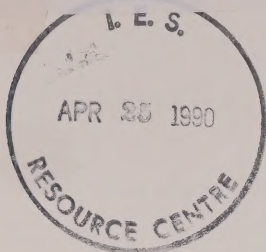


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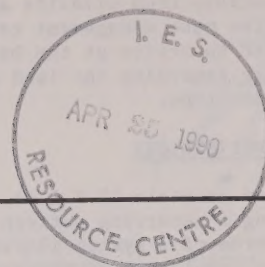


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BIOPHYSICAL CLASSIFICATION IN NOVA SCOTIA

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INTRODUCTION

Biophysical classification in Nova Scotia originated as one of the many positive spin-offs of the Canada Land Inventory Program. Unlike many provinces, biophysical classification in Nova Scotia was first seen as a tool for providing relatively homogenous geographical and ecological units by which to summarize the resource information available within the province. This objective has undergone a gradual change, primarily due to the recent increase in funds allocated to forest development and management.

In the past, forest management decisions were based primarily on forest growth and yield measurements. Today, because of the need to maximize production of all products from wild-lands, there is a growing realization that resource management decisions must be based on a combination of considerations, including maintenance of site productivity, provincial resource goals, social values, wildlife and recreation considerations, and the inter-relationships between growth, yield, site factors and forest land input. The development, therefore, of resource management plans has become quite complex, requiring the assistance of specialists trained in the field of land classification and forest-soil-management input interrelationships.

In view of these facts, the Department of Lands and Forests has revamped its thinking on biophysical classification and is now actively considering the following program.

OBJECTIVES

1. (i) Divide the major crown land blocks into land systems and describe each land type primarily in terms of their pedological and topographical properties and vegetation. At this point, only land systems will be delineated. Land types will not be mapped, but their importance based on the area they occupy in each system will be specified. This rather extensive survey will provide the necessary physical and ecological information required

to prepared five-year crown land resource management plans. These plans are a prerequisite to the expenditure of funds under the pending Federal-Provincial General Development Agreement (GDA).

(ii) Determine one year in advance, the resource management inputs required for each land-vegetation type delineated in the annual operating plan.

2. Classify all provincial parkland from the standpoint of providing the biophysical information required for the development of a parks resource management plan.

METHODOLOGY

1. Acquire colour infrared aerial photographs (9" x 9" format - 3" super-wide angle lens; scale 1" = 1 mi) for the area requiring classification.

2. On these photos, delineate land systems with the aid of a stereoscope and land scale photos (1:10,000 or 1:15,840).

3. Stereoscopically locate one or more field plots on each of the land types in each system.

4. Visit each of the land type sample plots on the ground and complete the land type tally sheet (see Appendix 1).

5. Complete land system and land type summary sheets (see Appendix 2) upon return to the office. Completion of these summaries is based on the land type tally sheets, airphoto interpretation and knowledge gained through field experience. At this time, the original land system boundaries are adjusted if the field work indicates the need to do so. It is anticipated that steps 1 to 5 will provide the basic data required for the development of the five-year management plan.

6. Determine the management input(s) required for each forest type or site delineated in the

annual plan by intensive field sampling (i.e. every forest type) and the interpretation of large scale colour infrared photographs. At this point, specialists from wildlife and recreation will also make management recommendations in order to arrive at the best possible compromise regarding the land use of each land-vegetation type.

DEFINITIONS

Land System, mapped at scale 1" = 1 mi, is an area of land having a recurring pattern of land types. The area of a system is variable and depends on the complexity of terrain conditions but usually averages 2,000 to 4,000 acres in size. The system is defined by the following criteria:

- i Stoniness
- ii Topographic Pattern
- iii Topography
- iv Relief
- v Landforms
- vi Drainage Classes
- vii Rooting Depths
- viii Textures
- ix Parent Rock Types

Land Type, mapped at a scale of 1:10,000 to 1:15,840, is an area of land having a specific soil moisture regime, texture, consistency, structure, coarse fragment type, rooting depth, parent rock type, slope, and climatic exposure. The land type is, therefore, roughly equivalent to what foresters often refer to as a site type. More importantly, the land type provides the biophysical basis for intensification of resource management. Justification for this statement is based on the fact that the forest at any given period of time is the net result of the interaction of climate, relief, parent material, living organisms and time. Since these factors tend to be the same for a given land type no matter where it is located in the land system and/or district, the forest and its response to various inputs and disturbances also tends to be the same. Hence the land type, because it is recurring and because it is described in terms of its site and vegetation characteristics, provides the basis for:

- (i) extrapolating the management implications of research and operational experiments conducted on specific sites to all land types having the same site and climatic properties
- (ii) predicting the long- and short-term effect of management inputs and
- (iii) rationally choosing from among the management alternatives, those that are both economically and ecologically sound.

MANAGEMENT INPUTS

The management inputs required for each forest type or site delineated in the annual plan will be decided primarily on the basis of the following interrelated factors. Examples of management inputs which are dependent or semi-dependent on each of the factors are listed in brackets.

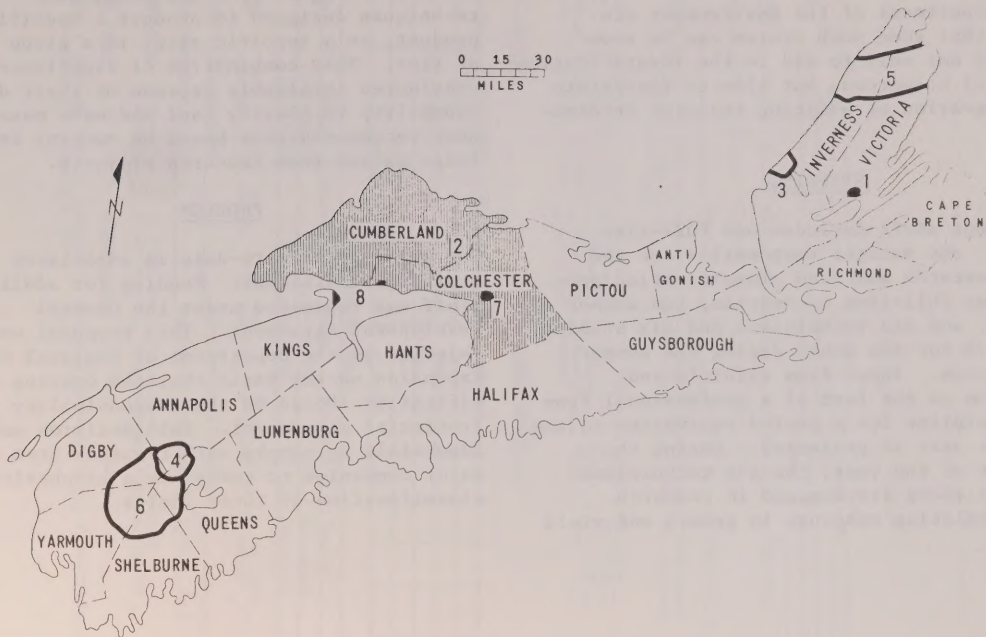
1. The silvical characteristics of the species or species association (method of harvest, selective, clear-cut, strip cut, etc.) rotation age, final products, spacing schedule)
2. Damage or projected damage by insects, diseases or animals (porcupine) (liquidation, spacing, early harvest, artificial reforestation with species resistant to the damage agent)
3. Presence or absence of advance regeneration (need to artificially reforest, logging method)
4. Soil depth, texture, moisture, rock type, etc. (final product, logging method, species, stock type and stock quality to plant, logging season, harvest method, site preparation method, spacing, chance and regime)
5. Surficial and underlying stoniness and rockiness (site preparation method, harvest method, reforestation method)
6. Stand density and stocking (spacing regime, harvest method, liquidation, rotation age)
7. Climatic factors - distance from coast, elevation, etc. (harvest method, species to plant)
8. Lesser vegetation (site preparation method, species, stock type and stock quality to plant)
9. Stand age or maturity (harvest, space, salvage)
10. Wildlife and parks considerations.

AREA COVERED

To-date, several variations of biophysical classification have been undertaken in different parts of the province (Figure 1). A brief description of each project is as follows:

1. Baddeck Area - Pilot project sponsored by the Department of Forestry and Rural Development. Area covered = 47,360 acres. Classification by Dr. G.K. Rutherford *et al.* Completed in 1968.
2. Cumberland and Colchester Counties - Pilot project undertaken by the Nova Scotia Department

Figure 1: Map of Nova Scotia



of Lands and Forests (NSLF). Area covered = 1,978,000 acres. Aerial multispectral imagery supplied by the Canada Centre for Remote Sensing. Estimated completion year 1977.

3. Mabou Highlands - Proposed provincial park. Estimated completion year 1976. Classification by NSLF.

4. Kejimikujik National Park - Area covered = 64,000 acres. Classification by Forest Management Institute and Acadia University. Completed in 1975.

5. Cape Breton Highlands National Park - Area covered = 240,000 acres. Classification by Eastern Ecological Research. Estimated completion year 1977.

6. Tobeatic Resource Management Area - Area covered = 336,000 acres. Classification by NSLF and the Canadian Forestry Service (CFS). Completed in 1975.

7. Manganese Mines Resource Centre - Student and teacher ecological educational training centre established by the Nova Scotia Teachers College. Area covered = 560 acres. Classification by NSLF. Estimated completion year

1976.

8. Various Provincial Parks - Area covered = 106,400 acres. Classification by NSLF.

ANTICIPATED FUTURE BIOPHYSICAL PROGRAM

1. Crown Lands - It is projected that under existing manpower and funding, approximately 15,000 acres per year can be classified on the extensive basis required for the development of five-year management plans. A further 10,000 to 15,000 acres, depending on the mix of stand conditions, can be classified on the intensive basis required for the development of annual management plans.

2. In September 1975, the Nova Scotia government resolved to undertake the development of a coastal zone management plan. Accordingly, it has established and funded a coastal zone management office in the Nova Scotia Department of the Environment. The identification, acquisition, and organization of information about the biological and physical characteristics of the Nova Scotia coastline will be an important input into the coastal zone planning process.

The value of a biophysical classification for coastal zone planning and management has not yet been clarified. Officials with the Nova Scotia Department of the Environment are hopeful that some such system can be soon developed not only to aid in the identification of coastal resources, but also to facilitate the integration of existing resource information.

STAFFING

The present staff includes one full-time forester, one manager responsible for the forest research and land classification programs, one full-time technician, two summer students, and six technicians and six student assistants for the month during the summer field season. Input from wildlife and recreation in the form of a professional from each discipline for a period equivalent to one month per year is projected. During the remainder of the year, the six technicians mentioned above are engaged in research studies relating response in growth and yield

to various management inputs and site factors. The long-term intent of these studies is to develop ecologically sound management techniques designed to produce a specific product, on a specific site, in a given length of time. This combination of experience is considered invaluable because of their dual capability to classify land and make management recommendations based on current knowledge gained from research projects.

PROBLEM

The major problem to-date is associated with staffing limitations. Funding for additional staff was requested under the General Development Agreement. This proposal was rejected by the Department of Regional Economic Expansion on the basis that the ongoing classification should be the responsibility of the Provincial Government. This decision makes it impossible to comply with requests from the major companies to carry out a biophysical classification of their limits.

Appendix 2: Data Summary Sheets

Land System

Land System No.		Land System Name			
Symbol		% Land Types		Forest Classification	
				Eco-Region	Site District

Area	Present Land Use	Forest Cover Type	Land Owner	Soil Catenas	
C.L.I. Classification					
Forestry M.A.I.	Symbol	Wildlife	Recreation	Agriculture	

Land Type

Land Type No.		Area		Land System No.			
Symbol		C	Forestry	Size			
		L	Agriculture	Space			
		I	Wildlife				
			Recreation				
Chrono Sequence							
Vegetation	Tree Species	Present	Fire	Cut	Barren	Pasture	Field
	Ground						
Management Recommendations For Forestry							
Logging		Site Prep.	Suggested Planting (sp.)		Recommended Prod.		
Method	Chance	Season	Rating	Ericaceous	Non-Ericaceous		
Management Recommendations							
Wildlife		Recreation		Agriculture			

PRESENT STATUS OF BIOPHYSICAL ACTIVITIES IN MANITOBA

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ABSTRACT

Manitoba initiated a biophysical program for the mid-north portion of the province in 1974. To-date, fieldwork for six and one-half 1:250,000 map sheets has been completed, and two and one-half map sheets are planned for 1976. The program operates on an annual budget of \$140,000 with a staff of six plus office technical support. The program is planned to continue at this rate until all of Manitoba where communities exist is mapped.

The geography of Manitoba is such that the major land-based activities occur in the southwestern quarter of the province, and it was this portion of Manitoba that was surveyed under the Canada Land Inventory. Resource and base line information in the North remains sporadic, nonexistent, inconsistent in methodology, etc. With the provincial government's firm commitment to increased development of the North for direct benefit to the people of the many dispersed communities in these regions, it became evident that some systematic approach to acquiring base line and resource information had to be initiated.

In 1974, a biophysical land classification program was initiated. The intent was to develop a program specific to identified Manitoba needs, and to map all of Northern Manitoba on a reconnaissance basis (i.e. at the land systems level). The total area represents approximately thirty-one 1:250,000 map sheets. During 1974-75, the program was developed and fieldwork was completed for two 1:250,000 map sheet areas. This was followed by four and one-quarter map sheets in 1975-76 and will be followed by approximately two and one-half map sheets this year, making a total of roughly nine map sheets. Specifics and methodology will be discussed by Gordon Mills, project leader of the biophysical team. It is planned that the operation will continue at approximately the same rate until, if not all of Northern Manitoba is mapped, at least the

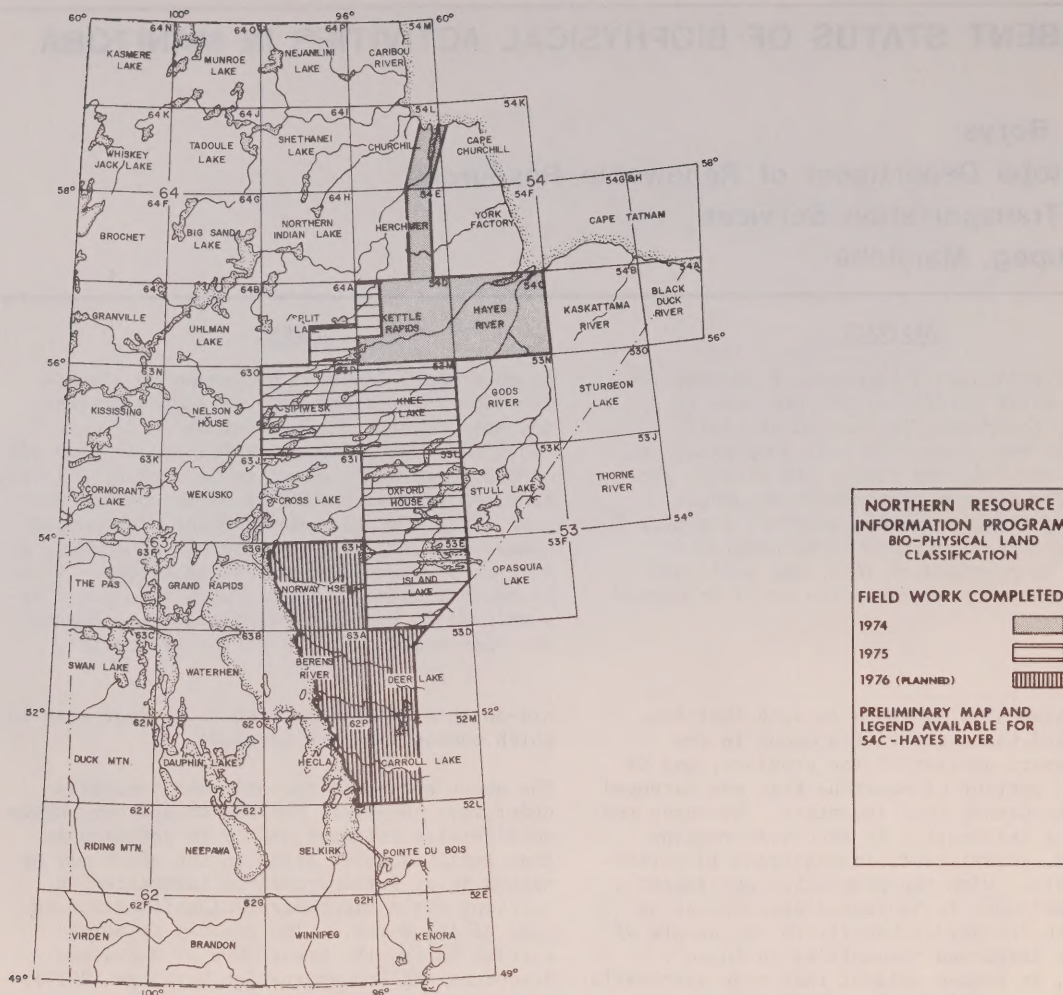
RESUME

Le Manitoba a lancé un programme de classification biophysique pour la région septentrionale moyenne de la province en 1974. Jusqu'ici, les travaux sur le terrain pour six cartes topographiques et demie (1:250,000) sont terminés et deux cartes et demie sont prévues pour 1976. Le programme dispose d'un budget annuel de \$140,000 et occupe six personnes, en plus de personnel de soutien technique. Il se poursuivra au même rythme jusqu'à ce que l'ensemble de la partie du Manitoba qui présente des communautés ait été portée sur cartes.

mid-north will be completed (i.e. that area in which communities are located).

The above survey is the only one currently under way. However, various groups have shown considerable interest and it is conceivable that small isolated areas in the south may be mapped (e.g. Parks Branch is interested in carrying out a biophysical classification in some of its parks). The program is being carried out by the Department of Renewable Resources and Transportation Services (RRTS). However, the team itself is composed jointly of staff from RRTS and the Soil Survey Unit which is associated with the Soil Science Department at the University of Manitoba. RRTS has placed on the program two professionals and one technician. Soil Survey has contributed the equivalent of two professionals, one technician, and technical assistance as required for soil analysis, drafting, etc. The joint effort appears to be working well and has created an excellent liaison between the University and the government department. Private activity is currently limited. However, a local consulting firm is in the process of establishing expertise in this area and is actively seeking contracts.

The Manitoba project is modest financially, with a current budget of \$140,000 plus soil survey input of approximately \$75,000. This will not likely be increased substantially. However, a strategy for greater economic development as relating to northern communities is being



developed by the province and demands may be made for a survey at the land type level. However, such a survey would be confined to areas selected on the basis of the reconnaissance survey.

Attached to the biophysical team last year, RRTS provided a wildlife biologist. His task was to make the biophysical information more usable and more readily interpretable by wildlife people. A preliminary report was produced, primarily as it related to the Hayes River map sheet. Critical evaluation of the report revealed that the work done by the biologist was useful but, invariably, more information was requested, information that could not be provided within the existing budget. Currently the wildlife component is being dropped and replacement of staff will consist of expertise in the biophysical area.

One major concern that Manitoba has relates to the lack of a classification for water bodies. Initially the program was quite ambitious and it was hoped that a reconnaissance water classification would be developed concurrently with the land classification. However, this did not materialize although basic water information was collected during the first two field seasons. Unless there is renewed demand for such a classification and increased budget it is unlikely this component will be developed and carried out under the present program. At this stage it is not possible to assess the usefulness of the maps for environmental impact assessment, planning, etc. Only one map has thus far been published. Much interest in the program has been shown and numerous requests for the map have been made, but direct feedback from users has not occurred.

SOIL SURVEYS IN THE CANADA DEPARTMENT OF AGRICULTURE

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ABSTRACT

Soil surveys of Agriculture Canada have evolved from traditional agricultural orientation to more diverse uses. At the same time, methodology has changed and some recent projects have utilized approaches closely resembling the biophysical scheme. Coordinated through the Canada Soil Survey Committee, surveys have responded to the rising volumes of soil data with the aid of a computerized data system (CanSIS). New information has necessitated modifications of the taxonomy to accommodate the total population of Canadian soils, and more refined methods of interpretation. This process of adaptation will continue in cooperation with other agencies, in particular the Canada Committee on Ecological (Bio-physical) Land Classification.

RESUME

Les relevés des sols effectués à Agriculture Canada, jadis axés sur la seule vocation agricole, s'intéressent maintenant à des usages plus diversifiés. La méthodologie a elle aussi changé; certains projets récents ce sont fondés sur des approches qui s'apparentent beaucoup au cadre biophysique. Coordonnés par la Commission canadienne de pédologie, ces programmes ont donné suite au volume croissant de données sur les sols au moyen d'un système informatique (CanSIS). Des renseignements nouveaux obtenus ont amené des modifications à la taxonomie de façon à pouvoir servir pour la grande variété des sols canadiens, ainsi que des méthodes d'interprétation plus perfectionnées. Ce processus d'adaptation se poursuivra, de concert avec d'autres organismes, notamment le Comité canadien de la classification écologique du territoire.

Agriculture Canada's work in soil survey is part of a national survey program involving a cooperative and integrated effort by both provincial and federal agencies. Soil survey has traditionally been oriented to some specific purpose. The earliest work in Ontario at the turn of the century was directed towards increasing the province's food producing capacity; in the Great Plains, surveys were started to aid land settlement and combat critical soil erosion; in present-day Ontario, most effort is concentrated on resolving urban-rural

conflicts and providing detailed information on soils for zoning and intensive agricultural management.

Not all soil survey work has been directed to agriculture; increasingly, soil survey has been used for non-agricultural purposes. Soil information obtained in regular soil surveys has been interpreted for forestry, engineering, urbanization, recreation assessment, and other purposes. Examples are listed in Table I. With current interests in resource conservation and

Table 1: *Typical modern routine surveys with interpretive material*

<u>Province</u>	<u>Survey</u>	<u>Date</u>
BC	Tulameen	1974
Alberta	Oyen	1976
Sask	St. Walburg	1976
Man	Morden - Winkler	1973
Ont	Waterloo	1971
Que	Chicoutimi	1971
NB	Rogersville	(in preparation)
NS	Cumberland	1973
PEI	PEI 1:10,000 series	(in preparation)
Nfld	Gander - Gambo	1972
NWT	Slave River Lowland	1972

management, soil survey has been involved in a growing number of comprehensive biophysical-type surveys that treat the soil component in its environmental perspective. These have included integrated or multidisciplinary approaches and have been carried out for a variety of requirements, including environmental impact assessment, comparative resource appraisal, parks planning, and other purposes. The projects of this kind in which Agriculture Canada has been involved are listed in Table 2.

Both the traditional general purpose survey and the special purpose-oriented survey are now focussing more on total landscape relationships. This is especially true of the low intensity special surveys in more remote areas, many of which might be labelled 'biophysical'.

The interpretation and application of soil survey information for land management and planning purposes has led to the development of the Canadian Soil Information System (CanSIS). This computerized data management system accommodates information relating to soil morphology, management, productivity, and geographic distribution. Currently all survey data and maps are being entered into the information bank, and CanSIS has been expanded (in cooperation with Parks Branch, Department of Indian and Northern Affairs) to accommodate soil and related data required for parks management and planning.

Recently Agriculture Canada has embarked on a land evaluation program involving the synthesis of pedologic, landform, climatic, agronomic and economic data to determine the relative

qualities of land areas, viable alternate uses, and inputs necessary to optimize utilization. The integration of provincial and federal soil survey activities is achieved through the Canada Soil Survey Committee (CSSC). The first meeting of the CSSC (then the National Soil Survey Committee) took place in 1945 with the objectives:

1. To provide greater efficiency in soil survey work by:
 - (a) bringing about a greater measure of uniformity between provinces in all phases of soil survey work
 - (b) utilizing the joint experience and efforts of the soil surveyors toward the solution of common problems affecting their field work
 - (c) providing a clearing house whereby any new developments or improvements in technique in any one province can be made available to all others in this field in Canada.
2. To recommend the location of areas where soil survey work should be done in relation to land settlement or for other purposes.
3. To act as an advisory body on soil survey matters to the parent Canadian Agricultural Services Coordinating Committee.

One of the main concerns at the 1945 meeting was the development of a soil classification system for Canada, and this has continued as the committee's primary responsibility. The first soil taxonomic system for Canada, estab-

Table 2: Comprehensive biophysical-type surveys

Province	Survey	Date
BC	Smithers - Hazelton	1972
BC	Nechako - Francois Lake	1974
Alta	Hinton - Edson	1973
Alta	Waterton Lakes National Park	(in press)
Alta	Yoho National Park	(in progress)
Alta	Banff - Jasper National Park	(in progress)
Sask	Prince Albert National Park	(in progress)
Man	Cormorant Lake	1975
Man	Winnipeg Regional Study Area	1975
Man	Churchill - Nelson River	1973
Ont	Pukaskwa National Park	(in press)
Nfld	Botwood	(in progress)
Nfld	Sandy Lake	(in progress)
NWT	Mackenzie River	1973
NWT	Somerset and Prince of Wales Islands	1976
NWT	Boothia	(in progress)
Yukon/NWT	Liard and Mackenzie River	(in press)

lished at the 1955 meeting of the CSSC, had six categorical levels corresponding to order, great group, subgroup, family, series and type. The orders recognized in the 1955 system were Chernozemic, Halomorphie, Podzolic, Forested Brown, Regosolic, Gleisolic and Organic.

The classification system has been modified, refined, and expanded continually over the past twenty years at the deliberations of the CSSC. The national classification system that was first accepted for general use in 1960 has resulted in "The System of Soil Classification for Canada" which is published and revised regularly by Agriculture Canada under the auspices of the CSSC.

Like any scientific endeavour, soil survey is a changing and developing field and one of the main functions of the CSSC has been to embody those changes and developments into a comprehensive national system. This of course is a continual process and, as many know, the CSSC has been criticized for its frequent modifications to the soil classification system and occasional apparent lack of consistency. The

period from 1945 to the present, however, has been one of rapid advances in pedology and greatly expanded field activity and the CSSC simply had to accommodate to the realities of the science. One such reality has been the waxing flood of hard data from recent surveys, which corroborated parts of our classification and parts of our methodology, but elsewhere established new norms. Even though a national committee may have a major responsibility for ensuring consistency and continuity, it must be prepared to experiment, adapt, and if necessary retract in order to provide the kind of national leadership required.

The CSSC sees a continuing need for change and improvements in the future. The systematization of soil survey interpretations for land management and planning, and the rationalization of soil mapping systems will be two of the major immediate concerns of the committee. The CSSC looks forward to cooperating with the Canada Committee on Ecological (Bio-physical) Land Classification in the development of an effective physical land classification system.

LAND INVENTORY PROGRAMS IN NEWFOUNDLAND

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ABSTRACT

Newfoundland had an active land inventory program during the late 1960's. Since that time, not much emphasis has been placed on land classification. Recently, however, with the major thrust to develop the north, there is a need to provide new information on land resources. Some comments are given on the experience to date in biophysical land classification in Newfoundland.

During the late 1960's and until 1971 there was an active land inventory program in the Province. In addition to the Canada Land Inventory, the following specific projects involving biophysical surveys were conducted.

1. Land Classification of the Corner Brook Area.
2. Biophysical Land Classification of the Goose Bay and Lake Melville Area.
3. Biophysical survey of the Badger Area-Newfoundland.

These projects were significant in the testing and finalization of methodology and on providing the opportunity for staff to become familiar with biophysical concepts and their value in resource planning.

The initial thrust in land classification was followed by a period of reassessment of provincial needs. Inventory programs involving land classification received low priority and professional and technical staff were assigned new responsibilities. However, in the interim, the Province embarked upon several major resource development programs in the north. For example:

1. A power development at Gull Island on the Churchill River will create a man-made lake 140 miles long.

RESUME

Il y a eu un grand programme d'inventaire des terres à Terre-Neuve vers la fin des années soixante. Depuis ce temps, toutefois, la classification du territoire n'a pas compté parmi les activités prioritaires. Etant donné l'intérêt récent pour la mise en valeur du Nord, il est devenu nécessaire d'obtenir de nouvelles données sur les ressources terrestres. Le présent document comprend des observations faisant suite aux expériences réalisées jusqu'ici dans le domaine de la classification biophysique de territoire à Terre-Neuve.

2. A transmission line from this hydro site across Labrador to the Island.
3. A trans-Labrador highway is being considered.
4. A uranium mine is in the final stages of planning at Postville, Labrador with production expected to start in two years.
5. The recent encouraging gas and oil discoveries in the Labrador Sea may have drastic consequences for the life of the coastal population.

In addition to the above development programs, native land claims are reaching the stage where presentations to government are expected soon.

With the coming of the age of environmental impact studies, there was a sudden need for reliable and accurate information on the land resources. While attempting to evaluate development proposals, it was soon realized that there was a serious lack of information. Impact studies hastily compiled in the absence of essential resource data have not served intended purposes.

The preceding has served to give you an indication of the basis for some of our present programs in land inventories. There are four current projects which should be identified.

While two of these are preliminary, they reflect some of our requirements.

1. A Coastal Inventory Program was conducted in 1975 in conjunction with the Lands Directorate of Environment Canada for two locations in the Province. The published maps are on display here today for anyone interested. The Department of Regional Economic Expansion (DREE) has agreed in principle to financially assist the Atlantic Provinces in carrying out an expanded program. In Newfoundland, priority will be given to the Island and the southern one-third of coastal Labrador if an agreement is entered into.

2. During the past several months, the Department of Forestry and Agriculture and Atlantic Lands Directorate of Environment Canada have developed a joint proposal to carry out a biophysical survey of Labrador at the land system level. If approved, it is expected that this project will take at least four years and will involve both federal and provincial scientists. This year, a preliminary assessment of Labrador will be undertaken by Lands Directorate staff on a strictly informal basis, using remote sensing techniques. Logistic support in terms of flying time and cartography will be provided by the Province.

3. The recent Royal Commission Report on Labrador recommended that a land resources inventory be initiated immediately for priority areas of Labrador. In addition, a Federal-Provincial Project Group has been studying the economic opportunities for Goose Bay following the phase down and eventual closing of the U.S.A.F. Base. A tentative agreement has already been worked out with DREE for providing financial assistance for developing industrial opportunities in this area. This agreement is presently open-ended in that it contains a general clause which could allow for further resource inventories as well as socioeconomic studies in Labrador.

4. A new forest management program is underway and an important element in the policy is a large scale silviculture program. If maximum benefit is to be derived from these expenditures, it will be necessary to have detailed ecological information on all sites. The biophysical concepts are well suited to present the essential information that the forest manager requires to make informed decisions. Although it is not underway, one does not have to be a prophet to envisage a program of land type mapping prior to initiation of intensive forestry management practices.

In concluding the remarks on the programs

underway or planned in the Province, it is suggested that benefits could accrue if all four were gathered under an 'umbrella' arrangement for direction and funding purposes. If not, there exists the possibility of a lack of coordination resulting in duplication of effort and a failure to focus on socioeconomic aspects of our land resources.

The major effort to date in biophysical classification was the project in the Goose Bay area in 1971 covering an area of 4100 mi². There were several positive features about this initial attempt as well as a number of limitations which are perhaps worthy of note so that others can gain from our experience.

1. There was a team made up of people from the following disciplines: soil science, wildlife biology, botany, ecology, forestry and recreation. These team-members worked together as a unit in the field. However, they were not committed to the project full time and as a result, this made the final compilation of reports and maps nearly impossible. Serious problems can result if personnel have to be distracted by other work commitments.

2. The Geological Survey of Canada, under the Direction of R. Fulton, developed a landform classification which is recommended for future use. If a genetic classification such as the one by Fulton were adopted on a national scale by all land ecologists, it would facilitate an understanding of each other's work and provide a common format for data collection eliminating duplication of costly field studies. Nearly all of southern Labrador has been mapped for surficial geology at the 1:50,000 scale, and this will be of tremendous value in future biophysical surveys.

3. In the north there is always the need to cover large areas. The experience in Goose Bay suggests that the area be mapped or studied one land region at a time. If field work is conducted concurrently in several land regions, masses of data will accumulate. Ideally, one region should be studied and all the vegetation successions worked out before moving to the next region.

4. If vegetation descriptions and successional patterns are not prepared for each land type, there may be severe limitations in assessing the true impact of any development proposal. This raises the question of mapping only at the land system level and how much detail can be obtained in a fixed time frame with cost restrictions.

5. Due to the non-availability of a hydrologist, no attempt was made to incorporate an

open water and wetland classification in Labrador. It is recommended that for future work this inadequacy be corrected.

In summary, our experience in Newfoundland indicates that the biophysical concepts are sound. If this information were available, it would contribute greatly to the understanding by the land manager of the resources and their best use. However, we recognize that, like all sciences, land classification is not static but will change and improve with new ideas and techniques. The Canada Committee on Ecological (Bio-physical) Land Classification will no doubt provide a major opportunity to share our experience and thus result in better utilization of our land resources.

RECENT DEVELOPMENTS IN ECO-CLIMATIC CLASSIFICATIONS

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ABSTRACT

Eco-climatic classifications have been produced on an ad hoc basis for various uses in Canada, but many fundamental problems remain in deriving systems having more universal applications. There is a need to incorporate more measured site-specific data into biophysical land surveys. Also, the existing meteorological network data can be used to greater advantage. To illustrate strengths and weaknesses in our present state of eco-climatic knowledge, this paper comments on four types of classifications.

RESUME

Diverses classifications écoclimatiques ont été réalisées, pour divers usages, au Canada dans le cadre de projets spéciaux, mais de nombreux problèmes fondamentaux demeurent sur le plan de l'analyse des systèmes dont l'application est plus universelle. Il existe un besoin d'incorporer dans les relevés biophysiques des terres un plus grand nombre de données provenant de mesures effectuées dans des endroits spécifiques. Il reste aussi encore beaucoup à faire pour en arriver à une meilleure utilisation des données provenant des réseaux météorologiques existants. Le présent document étudie quatre types de classifications destinées à illustrer les points forts et faibles dans l'état actuel de nos connaissances

INTRODUCTION

Climate is a primary factor influencing ecological systems on all scales. Nevertheless, the climatic factor has not always been well-integrated into the scientific appraisal of land as practised in Canada. Many explanations are possible, including, among others, network deficiencies, a paucity of specialists, and imperfect communications. Over the years, however, some progress in developing climatic classifications useful for land management can be noted. Four such classifications are discussed in this paper.

- (a) Inferential Classifications
- (b) National Classification for Agricultural Capability (CLI)
- (c) Regional CLI-type Classifications
- (d) Rational Classification for Recreation and Tourism

INFERENTIAL CLIMATIC CLASSIFICATIONS

This is the simplest of the classification methods, but can be the most demanding in terms of judgement skill. Here, climate is *inferred* from vegetation, soils or landforms. Few actual measurements are introduced beyond

certain base information, said to represent a particular ecological regime. Changes, reported in terms of colder, wetter, drier, etc are noted as tree species, soil units, or slopes change. The techniques have been well described by Hills *et al.* (1970) and Jurdant *et al.* (1974). While the method functions reasonably well when employed by experienced field workers, professional judgement is critical, and the lack of actual measurements makes the climatologist sceptical. Biophysical field parties should make use of meteorological instruments to check inferred climatic boundaries. Such measurements provide real information on present conditions and form the statistical base, the essential predictive element of the science.

THE (CLI) NATIONAL CLASSIFICATION FOR AGRICULTURAL CAPABILITY

In 1966 Chapman and Brown generated a combination of temperature and moisture indices computed from the records of the national meteorological network. From their computations, 40 agroclimatic regions in southern and non-mountainous districts of Canada were distinguished.



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The principal difference between national and regional classifications is that in the latter, temperature-moisture indices are ranged to identify seven land classes based on progressive climatic limitations to varieties of agricultural crops. The seven-grade system is a modification of the widely known United States soil capability classification. The classification system as used in British Columbia is illustrated by Figures 2 (British Columbia, 1972) and 3 (Can. Dept. of For., 1965). It may be noted that, in addition to

Figure 2: British Columbia agroclimatic capability classification

Class	Frost-free period (days)	Growing degree-days $\geq 5^{\circ}\text{C}$	Annual precip. (mm)	May - Sept. precip. (mm)	Climatic moisture deficit (mm)
1	90-120	1290-1620	<380	<230	Nil or small
2	75-90	1145-1290	<380	<200-250	40-1120
3	60-75	1000-1145	<330	<215	120-190
4	50-60	1000-1145			190-265
5	30-50	735-1000			265-345
6	<30	500-735			345-405
7	<30	<500			

Sub-Classes

- A Drought, aridity
(climatic not pedological moisture deficit)
- E plant injury to dormant trees by low winter temperatures
- F plant injury by low temperatures during growing season
- G insufficient heat units during the growing season
- H low temperatures during growing season which severely lower heat unit accumulation
- U wind exposure severe
- X combination of low temperatures, low heat accumulations, high snowfall, excess winds
- Y excess precipitation during growing season (flooding, poor tractability, poor harvest conditions).

the seven primary divisions, there are a number of subclasses which either identify limitations that might be overcome through technology (e.g. soil moisture deficit overcome by irrigation), or allude to regional peculiarities not expressed by thermal or moisture indices (e.g. severe wind exposure).

The system has been applied with some success in British Columbia where the measuring network has been enhanced in order to document climates on the lower mountain slopes. However, contrasting conditions between the coastal maritime climates and the interior continental climates lead to problems in the use of simple linear thermal indices to suggest crop growth. Long frost-free periods and growing seasons near the ocean give a large accumulation of growing degree-days. However, the relationship of crop growth to temperature is exponential, and accumulations of heat units near the threshold value are of lesser importance to crop development than those

associated with temperatures around 20°C and higher.

THE B.C. AGROCLIMATIC CAPABILITY SYSTEM ADAPTED TO THE YUKON AND NORTHWEST TERRITORIES

Erratic agricultural settlement patterns by recent colonists in the North caused governmental bodies in 1974 to cease issuing land permits for three years pending climatic and soil surveys. The Atmospheric Environment Service, in cooperation with the Department of Indian and Northern Affairs, is currently carrying out field studies to enable 1:125,000 climatic capability maps to be produced in areas where soils are considered reasonable. The classification to be used is the British Columbia system. The opportunities for *crop calibration* are limited in the frontier zone, and clearly the longer photo-period during the early growing season, as well as permafrost occurrences, will affect certain crop regimes. For example, vegetables are more reactive to

Figure 3: Selected crops in correspondence with agroclimatic capability classification (B.C.)

CROPS	C L A S S E S						
<u>Vegetables</u>	1	2	3	4	5	6	7
Corn	X						
Asparagus	X	X	X	X			
Beans	X	X					
Beets	X	X	X	X			
Broccoli	X	X	X	X			
Cabbage	X	X	X				
Cauliflower	X	X	X				
Carrots	X	X	X	X			
Peas	X	X	X	X			
Potatoes	X	X	X				
Turnips	X	X					
Spinach	X	X	X	X			
<u>Fruits</u>							
Tomatoes	X						
Apples	X						
Strawberries	X	X					
<u>Forage Crops</u>							
Alfalfa	X	X					
Red Clover	X	X	X				
Alsike Clover	X	X	X				
Orchard Grass	X						
Brome Grass	X	X					
Timothy		X	X	X	X		
Native Browse					X	X	
<u>Cereal Grains</u>							
Wheat	X	X					
Oats	X	X	X	X			
Barley	X	X	X	X			

light variations than cereals.

The backbone of any classification system is a good data base. For this project, 50 new climatological stations were established in 1975. These were arranged in 15 transects to document elevation, slope aspect, vegetation and water body effects on temperature, humidity and precipitation. To judge the area the transects *represent*, mobile surveys using electrical sensors and recording equipment (mounted on a truck) were carried out in the Yukon Territory. This enables boundaries of influence to be better delineated than by using strictly vegetation and/or physiographic criteria. The details of parameter estimation over the diverse terrain of the Canadian North-west are beyond the scope of this paper. Procedures adopted have been based on known topoclimatic relationships, and height-dependency curves have been developed for the districts under study.

The research will be published in early 1977 but preliminary results indicate that cultivable lands (classes 1-4) in the Mackenzie District are generally below 950 ft (290 m) a.s.l. Some grazing (class 6) is feasible to 2,500 ft. (770 m). Poorly drained areas may be one or two classes lower because of low day-time temperatures and frost dangers. In the Yukon south of 64° latitude, by comparison, useful land extends up to 500 ft. (150 m) higher, though in the north and near the St. Elias Mountains, conditions are similar to those of the Mackenzie District. The lower elevations

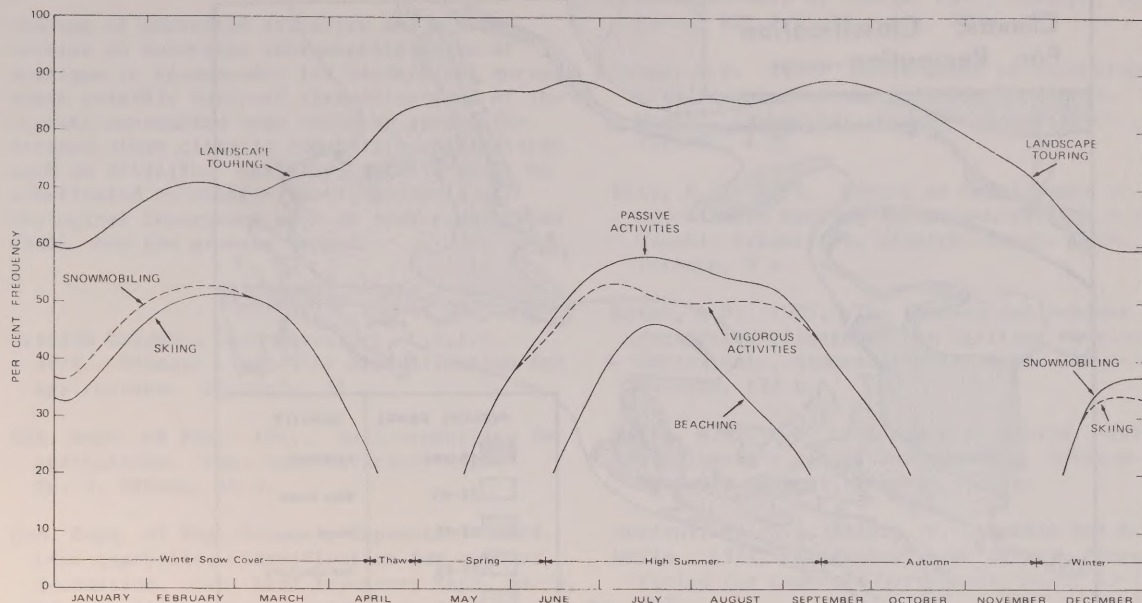
Figure 4: Criteria for recreational classification in the Atlantic Provinces.

Meteorological Factors	Humidex (effective temp.)	Visibility (mi)	Sky Cover (tenths)	Wind Speed m.p.h.	Snow Cover (inches)	Other Weather Contingencies
Landscape Touring	-12 to 89	> 3	n/a	≤ 25	n/a	nil
Passive Activity	> 54	> 1	< 8	≤ 20	n/a	nil
Vigorous Activity	55-89	> 2	< 8	≤ 20	n/a	nil
Beaching	> 64	> 1	< 8	≤ 15	n/a	nil
Skiing	> 6	> ½	n/a	≤ 15	> 1"	nil or S-, SP-, SW-, SG-,
Snowmobiling	> -6	> ½	n/a	≤ 15	> 1"	nil or S-, SP-, SW-SG.

Conditions to be met for 5 hours between 10 a.m. and 6 p.m.

S - light snowfall
 SW - light snow showers
 SP - light snow pellets (graupel)
 SG - light snow grains

Figure 5: Annual variation of "suitable days" - Charlottetown, Prince Edward Island.



of all Yukon valleys experience drought during the summer.

RATIONAL CLASSIFICATION OF CLIMATE FOR RECREATION AND TOURISM AT THE LAND DISTRICT AND LAND REGION SCALE (1:1,000,000)

Based on experience dating from 1970, the Atmospheric Environment Service has recently prepared a climatic overlay for the Canada Land Inventory recreation capability map of the Atlantic Provinces. The latter map was based on landscape amenities and aesthetics (Can. Dept. of Reg. Economic Expansion, 1969). The derivation of the climatic map was based on concepts developed by Crowe *et al.* (1973). A central theme is the *activity-day* which defines the possibility of undertaking with satisfaction certain groups of outdoor activities. Activities are divided into winter and summer varieties and further into passive and vigorous phases. Each activity group has meteorological limits, thresholds of temperature, humidity, wind velocity, snow cover, precipitation, etc. (Figure 4). Following the applications of activity-day criteria to the climatological records, seasonal lengths and seasonal qualities for outdoor activities may be designated.

The climatic capability maps were constructed as follows. A tabulation was generated to indicate the collective ten-day frequency of

activity-days for selected recreational pastimes over a ten-year period. The data were plotted as smooth seasonal curves for 48 stations (Figure 5). The area under each curve was measured. The station having the greatest seasonal strength (frequency-duration) was assumed to represent *ideal* conditions and was assigned a value of 100%. Appropriate percentages for the other 47 stations were then calculated. For example, Lake Eon, Québec received the highest regional strength value for skiing (100%) and Fredericton, N.B. was allocated 64%. Percentage values were then mapped for composite seasonal activities. Word descriptors indicating a range from excellent to unsatisfactory conditions were allocated at specific percentage values. The recreation climatic capability maps are shown as Figures 6 and 7.

DISCUSSION

For the purposes of this paper four types of eco-climatic classifications have been recognized from among several possibilities. One of the principal problems encountered in application is that each classification is valid for certain map scales and becomes difficult to transpose to other scales, particularly large scales in land type surveys (1:10,000 - 1:20,000). However, useful work on the district scale has been published by MacIver *et al.* (1972) for Alberta where data from a sparse network were statistically evaluated and allocated to

Figure 6:

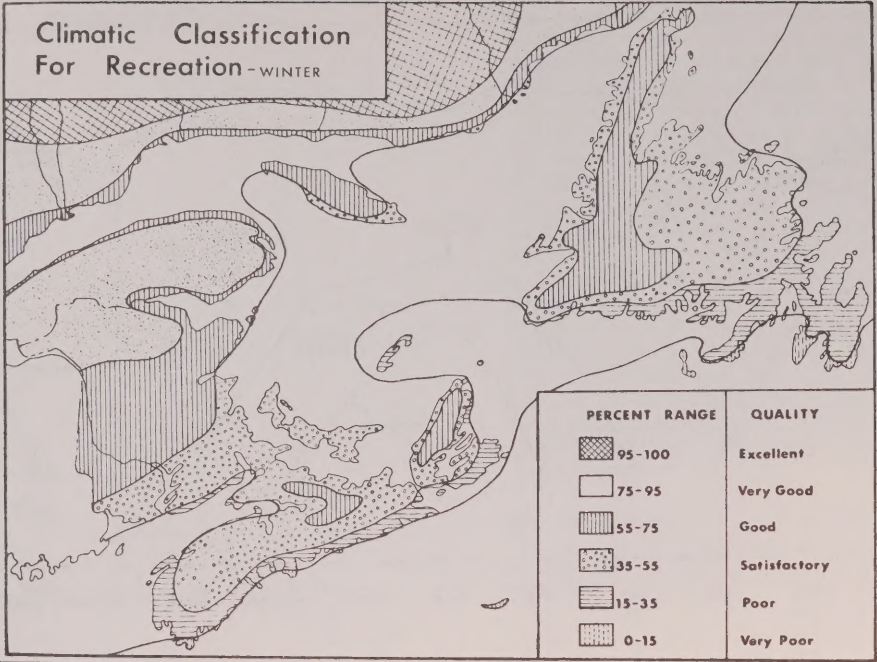
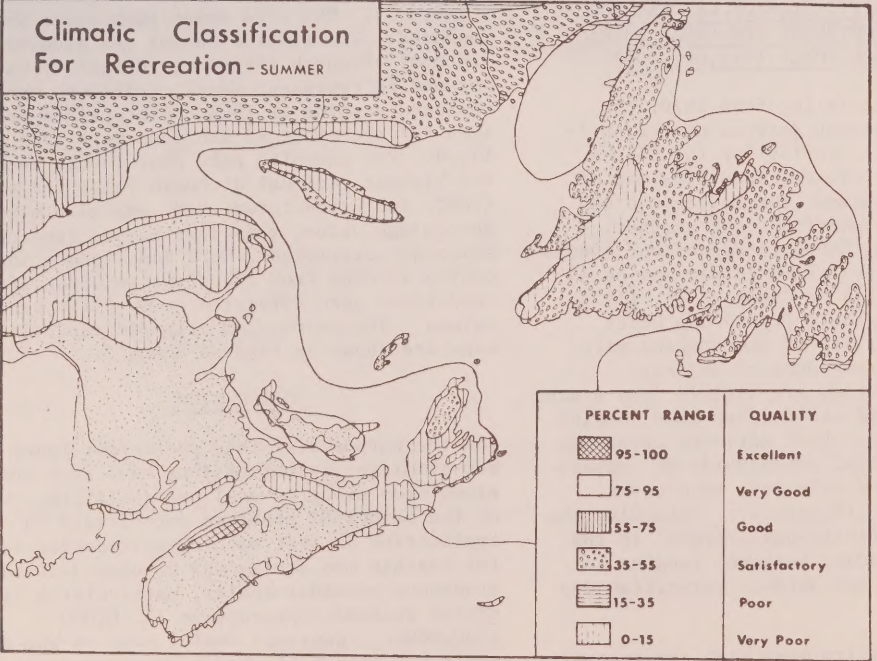


Figure 7:



groupings within homogeneous climatic areas.

The use of elevation transects and mobile surveys to determine representativeness of stations is recommended for biophysical surveys where possible *rational* classifications of the recreation-tourism type could be tested for certain other climatic capability applications such as wildlife. Activity criteria would be substituted by other climatic controls of biological importance such as snow cover, wind chill, and the growing season.

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BIOPHYSICAL-TYPE SURVEYS IN THE DEPARTMENT OF ENERGY, MINES AND RESOURCES

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The Terrain Sciences Division of the Geological Survey of Canada is the group in the Department of Energy, Mines and Resources that has been carrying out biophysical types of surveys. These are done under one of our major objectives which is to map, describe and explain the surficial materials of Canada in order to obtain information pertinent to land use, resource development, environmental concerns and activity of geological processes, and to determine the Quaternary history. It should be noted that this activity is oriented entirely towards the physical aspects of land. Biological aspects are not mentioned. In the south, biological aspects are generally completely ignored. In the north, however, it is necessary to consider them when looking at the physical side because in areas of permafrost they play an important role in the way in which the land reacts. In the south you can cut off the bush or turn over the sod and about all that generally happens is that you lose a little top soil. In the areas of permafrost, however, removal of vegetation can and often does lead to the interplay of a completely new set of physical-geological activities that can develop a new physiography and completely changes the way in which the land reacts. Consequently we have started work, that can be described as biophysical, where the biological side has potential to profoundly affect our prime field of interest, the physical side.

Purists might argue that because much of our work is not completely integrated it is not truly biophysical or ecological in nature. Our basic approach has been to have a geomorphologist subdivide the land into homogeneous units, and then have pedologists and/or

botanists characterize the plants and soils in each of these permanent or physical units and set up ecological districts and regions. This is single discipline work with an overlay of other disciplines. Pioneer work of this type was done in the Mackenzie Valley by Hughes and Rutter with the aid of Tarnocai and Zoltai. This work was extended further into the Arctic by Boydell and Tarnocai on the Boothia Peninsula, and recently to Banks Island by Vincent and Edlund, to Ellesmere by Hodgson and Edlund and to Somerset and Prince of Wales by Netterville, Zoltai and Woo.

A fully integrated approach has been applied by Barnett and co-workers in Eastern Melville, Bathurst and Cornwallis Islands. In this work, a hierarchy of units was used and biological factors were taken into account in fixing some unit boundaries.

In our present program, emphasis is on the Arctic gas pipeline route on the west side of Hudson Bay and on potential oil and gas producing areas in the Arctic Islands. Work is continuing on Banks Island.

Looking further into the future, there is some question as to how much more work of this type we will be able to do. The demise of the Environmental Social Program, Northern Pipelines will cut off our pipeline of funds from Treasury Board and stand-pat budgeting will force some retrenchment so that over the next few years we will probably have difficulty in finding enough resources to meet our primary physical objectives. However, this might be good because we might be forced into more joint projects with other agencies that could benefit both sides of the ecological coin.

BIOPHYSICAL LAND CLASSIFICATION OF BANFF AND JASPER NATIONAL PARKS

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ABSTRACT

The Banff-Jasper biophysical team accepts the basic concepts of a biophysical land classification system. Modifications to existing biophysical inventory methodology are described, including problems with classification methodology, and recommendations. Four appendices describe operational methodology, results to-date, user contact and anticipated applications, and problem areas.

RESUME

L'équipe biophysique des parcs de Banff et Jasper accepte les concepts fondamentaux d'un système de classification écologique du territoire. Le présent document explique les modifications apportées à la méthodologie existante l'inventaire biophysique, y compris les problèmes relatifs à la méthodologie de la classification et les recommandations. Quatre annexes décrivent la méthodologie opérationnelle, les résultats obtenus jusqu'ici, les contacts avec les usagers, les applications prévues et les domaines à problèmes.

INTRODUCTION

At the request of Parks Canada in 1973, a biophysical land classification was planned, in 1974, for Banff and Jasper National Parks and initiated by field activities in the Mt. Eisenhower-Lake Louise area of Banff National Park. The methodology of Lacate (1969) was adopted for trial. Field work was initiated in Jasper in 1975, and continued in Banff, with Lacate's methodology being modified and developed as described in this paper.

Detailed objectives of the Banff-Jasper inventory project are provided by Day *et al.* (1975) and reiterated in Progress Report No. 1 by Holland *et al.* (1975). The objectives of the project may be summarized as follows:

1) To quantitatively and qualitatively describe the landforms, soils and vegetation characteristics of both Parks - in map and report form.

2) To provide interpretation of data for Parks' purposes; eg. land use planning and management of land within the Parks.

The terms of reference (Day *et al.* 1975)

thoroughly outlines the basic data requirements in terms of a multi-disciplinary team approach to integrated resource inventory; thus, the adoption of a biophysical land classification system. They also provide for the inclusion of landform classification (Fulton *et al.* 1974); soil classification (Canada Soil Survey Committee 1970, 1973, 1974); wetlands classification (Zoltai *et al.* 1975); vegetation resource description and classification; wildlife resources. User requirements are described. Freedom is provided however, to permit development of integrated land classification methodology; for example, in the vegetation component of the inventory and as dictated by the scale of 1:50,000.

The main emphasis of this paper is on the classification methodology that is being used in Banff-Jasper and the development of the methodology, logistics, problems, etc. is presented in four Appendices to this paper.

CLASSIFICATION METHODOLOGY

A. Background - The basic concept or aim of biophysical land classification--namely, "to

differentiate and classify ecologically significant segments of the land surface" (Lacate 1969)--is valid and quite acceptable. The hierarchical levels of generalization (Lacate 1969, Jurdant *et al.* 1975) also have merit but problems in applying them in the Banff-Jasper Land Inventory Project arise for the following reasons:

1. Flexibility of application designed into definitions (Zoltai 1970) promotes somewhat variable interpretations of the various classification levels between team members.

2. Variability of mountain terrain and environments is a main problem area. In particular, vertical zonation, produced by altitudinal macro-climates, necessitates more complex and areally smaller separations at highest levels of generalization than have been recognized in several other projects across Canada.

3. The approximate scales as established by Lacate (1969) for a hierarchical biophysical system are not entirely adequate in the mountains and do not include the required project scale of 1:50,000.

4. Many ecologists feel that there is insufficient collection of basic environmental data in biophysical inventory projects. These data are generally not available but are necessary to explain ecological relationships and will add integrity to most interpretations. For the most part, these relationships are now explained by hypotheses. In addition, vegetation scientists desire, in biophysical classification systems, more meaningful hierarchical structure in terms of *ecological significance*. Consequently, modification and refinement of land classification concepts to-date have resulted in the Banff-Jasper Biophysical Land Classification System as presented in the following section.

B. Banff-Jasper Biophysical Land Classification System (Table 1) - Table 1 presents a breakdown (hierarchical levels of generalization) of the biophysical land classification system being used, and proposed for use, in Banff and Jasper National Parks. Levels 1, 2, 4 and 5 are presently operational (e.g. Lake Louise Study Area, Walker *et al.* 1976). Level 3 is presently under consideration as a means of grouping, at an intermediate hierarchical level, those Land Systems that have apparently similar environments.

The general objective of this system is to promote holistic, repeating, map unit concepts through integration of landscape components (landform, soil, and vegetation) within an

ecologically sound framework.

1. *Bioclimate Zone* (Level 1) constitutes the highest level of abstraction in the Banff-Jasper Biophysical Land Classification System. Separations at this level depict macro-climates, as expressed by vegetation, that are controlled mainly by elevation and partly by latitude and general east-west physiography.

2. *Bioclimate Subzone* (Level 2) identifies subdivisions of macro-climate based primarily on elevation differences as reflected by vegetation. For example, Upper Subalpine encompasses Subalpine vegetation types (usually (spruce/fir forests) that reflect, in this structure and species composition, near-Alpine conditions.

3. *Vegetation-Soil 'District'* (Level 3) is under consideration as an intermediate step for differentiating various environmental 'facies' within some of the more broadly defined Bioclimate Subzones. The basic concept for Level 3 was initiated when biophysical map units comprising the Lake Louise Study Area (Walker *et al.* 1976) were grouped for purposes of relating soil and vegetation development to inferred climatic trends existing in that area (see Figure 1). It is felt that adoption of this step for the overall inventory (1:50,000 scale) will add ecological integrity to the Banff-Jasper Biophysical Land Classification System. It must be pointed out, however, that the 'Districts' listed in Level 3 (Table 1) are highly tentative and reflect experience gained over one year in limited areas of both Parks.

Conceivably, Vegetation-Soil 'Districts' will depict trends in soil and vegetation development as influenced by *meso-climate* (or physiographic modification of macro-climate) interacting with latitudinal, elevational, and broad material (reaction and calcareousness) variations. Controlling physiographic parameters are east-west orography (Foothills versus Front Ranges versus Main Ranges) and, to a lesser extent, slope aspect in broad valleys. Specifically, climatic features such as snowfall (amount and duration), total precipitation, evapo-transpiration, and temperature can be qualitatively defined, on a relative basis, through an evaluation of trends in soil and vegetation development.

4. *Land System* (Level 4) is the basic conceptual level in the Banff-Jasper biophysical land inventory because Land Systems are the most consistent, repeating map concepts observable using air photos. Units that group or subdivide (above and below in the hierarchy) Land Systems are interpreted or identified as a

Table 1: Banff-Jasper Biophysical Land Classification (tentative)

LEVEL OF GENERALIZATION	1 BIOCLIMATIC ZONE	2 BIOCLIMATIC SUBZONE	3 VEGETATION-SOIL 'DISTRICT'	4 LAND SYSTEM	5 BIOPHYSICAL MAP UNIT
	ALPINE	Upper	Rock and lichen	Separations at this level are presently made within each Bioclimatic Subzone and are based on landform and major drainage features. Consequently, each Land System encompasses map units: 1. on similar geologic materials (consideration of origin, texture, and reaction); 2. of similar terrain surface form ^{4,5} (eg. aprons & fans vs. steep & inclined slopes vs. hummocky & ridged, etc.); and 3. having dominant soils of either: a) moderate to very rapid drainage - or - b) imperfect to very poor drainage. More variability is allowed in alluvial (recent) material characteristics than in other geomorphic materials. In addition, alluvial areas dominated by Regosolic soils (resulting from frequent flooding) are separated from alluvial areas with more advanced soils.	Each Land System is subdivided according to variations in soil and vegetation components as follows: - significant landform modifications (eg. inclusions of other materials, erosional processes); - significant variations in the proportions of component soils (phase of subgroups) and representative vegetation types; - significant inclusions of extraneous soils and vegetation types that influence overall use potential
		Middle & Lower ²	<i>Cassiope/Phyllodoce</i> --Brunisol/Regosol		
	SUBALPINE	Upper Subalpine	Spruce/fir-- <i>Cassiope</i> --Brunisol/Podzol Larch/fir--Brunisol/Podzol Spruce/fir-- <i>Vaccinium</i> --Brunisol/Podzol		
		Lower Subalpine	Spruce/fir-- <i>Menziesia</i> --Podzol Spruce/fir-- <i>Menziesia</i> --Podzol/Brunisol Pine (Spruce) - <i>Shepherdia</i> --Brunisol/Luvisol		
	MONTANE	(Middle & Lower) ²	White spruce/Douglas fir--Brunisol/Luvisol Grassland--Brunisol/Regosol		
	BOREAL	Upper Foothills ³	?		
BIO-PHYSICAL LAND CLASSIFICATION EQUIVALENTS ¹	LAND REGION (?)	SUBDIVISION OF LAND REGION	?	LAND SYSTEM (?)	SUBDIVISION OF LAND SYSTEM
1. Lacate 1969 2. La Roi <i>et al.</i> 1975 3. Rowe 1972 4. Fulton <i>et al.</i> 1974 5. Acton 1975					

secondary stage.

Separations at this level are based on the descriptive landform classification system initiated by Fulton *et al.* (1974) and modified by Acton (1975). Materials category (origin) and terrain surface form are the basic elements of landform classification considered in Level 4. However, texture, reaction, and calcareousness are also considered. Because of use implications in the mountain National Parks, areas dominated by poorly and very poorly drained (wet) soils are also separated, at Level 4, from areas dominated by better drained soils. Table 1 lists the criteria by which Land System separations are made.

At the present time, Land Systems are differentiated within Bioclimatic Subzone (Level 2) units. If Level 3 is accepted as part of the hierarchy, Land Systems will be

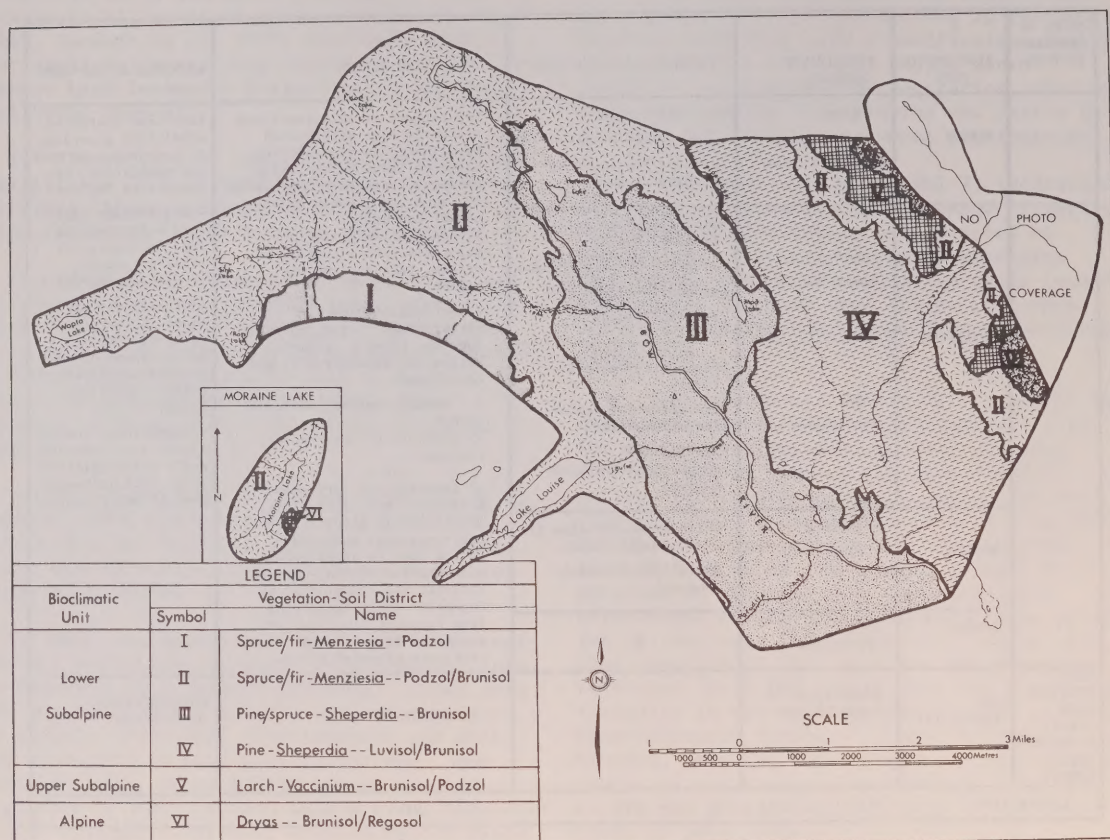
defined as occurring within Vegetation-Soil 'District'. Each Land System is identified by a geographic place name and, on maps, by a two-letter symbol.

5. *Biophysical Map Unit* (Level 5) is the main mapping level for the Banff-Jasper biophysical land inventory. Each map unit is identified by a two-letter symbol (indicating the Land System in which it belongs) plus a number.

Each Biophysical Map Unit indicates a pattern of soils and vegetation allowable within the geologic and environmental limits imposed by higher hierarchical levels in the classification system. Table 1 further specifies the criteria used to make map units separations.

The component soil (or soils) of biophysical Map Unit is recognized to be *subgroup phase*.

Figure 1: Vegetation-Soil "Districts" of the Lake Louise Study Area (from Walker et al. 1976)



Representative vegetation type (or types) constitutes the vegetation element of a biophysical map unit definition and is based on a taxonomic entity - the vegetation type. A vegetation type is the smallest vegetation unit discriminable floristically and environmentally and is comparable to *plant association* (*sensu* Braun-Blanquet as modified by Krajina 1960) or *biogeocoenosis type* (*sensu* Sukachev 1958, 1960).

Representative vegetation type is a new concept introduced as a mapping device (legend) in the Lake Louise Study Area (Walker et al. 1976). Since most map units are somewhat heterogeneous in terms of vegetative cover, one taxonomic vegetation type is selected to represent or characterize, in the legend, the vegetation of each map unit. This is the representative vegetation type of that unit. In most cases, representative vegetation type is the dominant type providing it is stabilized or mature and reflects model habitat conditions

of the map unit. Potential climax types need not be used as representative vegetation types. Short-term early or young succession stages (following disturbances) and introduced vegetation are not used. Types other than the representative vegetation type may in most cases be regarded as inclusions in a map unit. Some map units may be vegetationally characterized by up to three representative vegetation types. These are generally associated with complex landforms and habitats where landscape segments (e.g. north- versus south-facing slopes, dry versus wet portions) are defined in the legend or situations in which more than one vegetation type occupy nearly equal portions of the map unit.

C. Problem Areas - Problems other than logistics problems, but sometimes logistics-related, remain in the Banff-Jasper Biophysical Land Classification System concepts and their application.

1. *Cartographic Problems* - If rock, ice, and permanent snow fields are included within the concept of *Alpine*, Bioclimatic Zones (Level 1) are mappable at a scale of 1:500,000 and, perhaps, smaller scales. However, a major cartographic problem occurs in Level 2 because some bioclimatic subzones--namely Alpine areas exclusive of rock and ice and Upper Subalpine areas--are not mappable at scales smaller than 1:50,000. Nevertheless, bioclimate subzones (Level 2) are ecologically important areas and are used as an organizational tool to group units from lower levels in the hierarchy.

Vegetation-soil 'districts' (Level 3) should be mappable at 1:125,000 to 1:250,000 because they span material and landform boundaries. However, they occur within bioclimatic subzones (Level 2) are ecologically important areas and are used as an organizational tool to group units from lower levels in the hierarchy.

The cartographic problem pertaining to Level 2 also descends to Level 4 (Land System). In addition, land systems, as used in the Banff-Jasper biophysical land inventory, are conceptual rather than cartographic groupings of biophysical map units (Level 5 units). In other words, map units belonging to a land system seldom occur together in the landscape but are frequently separated by map units of other land systems.

Biophysical map units (Level 5) are utilized in the mapping and work reasonably well at scales of 1:20,000 to 1:50,000 in the mountain terrain.

2. *Data Requirements* - As previously mentioned in the *Background* subsection, most ecologists express a need for more intensive data gathering for purposes of identifying and explaining ecological relationships. In particular, vegetation scientists desire an intensive sampling program (amenable to statistical analysis) to adequately characterize and define limits for vegetation types. Beyond this, ecological (climate-vegetation-soil-geologic material) relationships, and resulting interpretations, could be more confidently established.

Although intensive sampling and characterization of vegetation is both necessary and desirable, time and monetary constraints limit such an approach and necessitate compromises in sampling intensity.

3. *Waterbodies and Wetlands* - To-date, operational mapping procedures within Banff and Jasper National Parks have not included detailed characterization of lakes and streams. The relatively small areal extent of waterbodies in sections mapped to-date has probably

been the main reason for this reduced concern. Recent contact with limnologists, hydrologists, and wildlife biologists suggests that more attention be given to aquatic ecosystems.

Present operational mapping in the mountain Parks recognizes waterbodies and associated wetlands only as accessory features of biophysical map unit (Level 5) definitions. However, guidelines for open water and wetland classification as outlined by Adams and Zoltai (1969) and modified by Jurdant *et al.* (1972) may be tested in the Banff-Jasper Biophysical Land Classification System in the near future.

4. *Classification System Problems* - Main problems in the Banff-Jasper Biophysical Land Classification System center around Level 3 and include naming of this category (use of 'District' may create confusion relative to Lacate's 1969 Land District definition) and its implementation within the hierarchical structure. Regarding the latter problem, several options are under consideration.

- a) Level 3 may be retained as a district category as shown in Table 1. Land System separations would be made according to the specified criteria (Table 1) but within each vegetation-soil 'district'.
- b) Levels 1,2,4 and 5 (Table 1) may remain operational and Level 3 will be used outside the system's hierarchy to group various soil and vegetation trends for discussion purposes. This option would necessitate mapping of Level 3 units to show climatic and distributional relationships.
- c) Levels 2 and 3 (Table 1) may be integrated into a single hierarchical category with less emphasis on the vertical (altitudinal) zonation imposed by Level 2. Such a move may alleviate, in part, the mapping problems associated with the Bioclimatic Subzone Level (see discussion under *Cartographic Problems*).
- d) Levels 2 and 4 (Table 1) may be integrated into one hierarchical category. Cartographic problems at such a level would, however, be compounded.

Some of the options will be subjected to testing and evaluation during the 1976 field season. In addition, more stringent criteria for Level 3 separations will be developed in the following year.

D. *Summary Discussion and Recommendations* - The Banff-Jasper biophysical team accepts the basic concepts of a biophysical land classifi-

cation system. It strongly feels, however, that many definitions of terms, taxonomic criteria, and hierarchical structure be made more rigorous. The trial, and/or adoption, of a restructured hierarchical classification methodology that provides for a category approaching Vegetation-Soil 'District' as described in the above text, is also considered very important.

Recommendations from the Banff-Jasper biophysical team are summarized as follows:

1. Development of more rigorous terms, definitions, taxonomic criteria, hierarchical classification structure throughout the entire biophysical system.

2. The Level 3 concept of Vegetation-Soil 'District' be further developed and adopted for trail.

3. Investigate methods of obtaining extra input from vegetation scientists into biophysical inventory by aiming their efforts towards further development and/or adoption of a unified framework for vegetation classification in Canada.

4. Exploration be made whereby basic data-gathering for vegetation and soils be made more extensive in order to identify and explain ecologically significant relationships that may be used to verify and strengthen interpretations.

5. Efforts be made to develop climatic data input into biophysical land classification methodology in order to assist in differentiation to the Vegetation-Soil 'District' Level (Level 3, Table 1).

6. Biophysical team members continue to develop user contacts and maintain some involvement with site specific problems and studies as a self-training tool (refer to Appendix C).

7. Efforts be made towards upgrading of user skills in understanding inventory methodology, resource analysis, and interpretative results by development and sale of a *Benchmark Training Manual for Biophysical Land Classification Users* (refer to Appendices C and D).

8. Research requirements be established in order of priority and methods of funding be investigated (refer to Appendix D).

9. Methods of providing publication assistance for biophysical projects be examined (refer to Appendix D).

ACKNOWLEDGEMENTS

The survey of Banff and Jasper National Parks is a joint project involving the Canadian Forestry Service, the Soil Research Institute and the Alberta Institute of Pedology.

Parks Canada is supplying the Major funding. Problem areas, data requirements, advice, and assistance have been, and are being received from Dave Day, C. Zinkan, and P. Benson, Western Region, Parks Canada, Calgary, and from Bruce Wilson, Tom Ross, the Warden Service and others in the respective Parks.

The project is receiving whole-hearted support from the Biophysical team members, namely:

Alberta Institute of Pedology:

Dr. Russ Well, Pedologist
Bruce D. Walker, Pedologist
Phil Epp, Pedologist
Ian Corns, Vegetation Scientist
Alan Westhaver, Vegetation Technician
Joe Tajek, Soil Technician

Canadian Forestry Service:

Dr. S. Kojima, Vegetation Scientist
Doug Allan, Soil Technician
Jack Dyck, Vegetation Technician

Soil Research Institute:

Dr. G.M. Coen, Pedologist
Dr. Julian Dumanski, Pedologist

The above personnel are all contributors, in one way or another, to reports emanating from The Banff-Jasper Project. The single name on the front of this document is convenient for referencing and queries.

OPERATIONAL METHODOLOGY

Figure A1 provides an overview of the position of the inventory team within the organizational framework of the entire resource inventory currently in progress in the mountain Parks.

1. Logistics

- a) high relief and terrain variability
- b) budgetary and Park restraints on use of helicopters
- c) slowness of ground access by foot and shortness of survey season
- d) limitations in available photography
- e) the amount of site specific work that is requested.

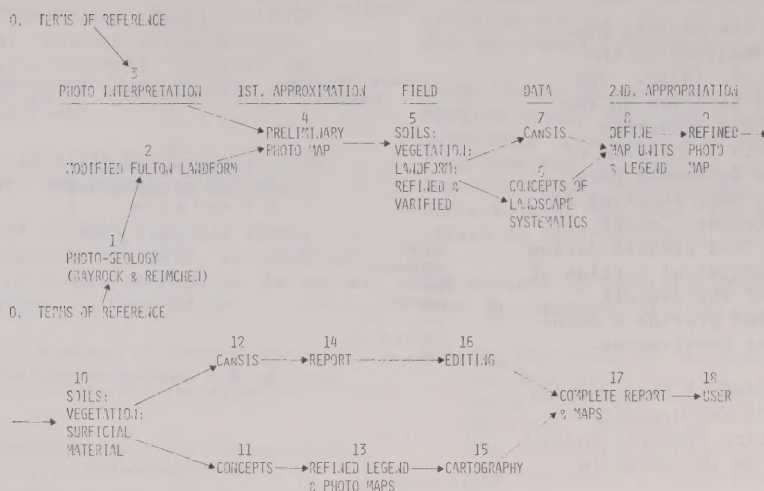
2. Air Photos

Figure A1: Biophysical inventory stages (Day et al. 1975)

Results of the color photography were disappointing for two reasons:

1. The 1975 flight was flown about July 3, just after a rather vigorous snowstorm, and
2. many of the valley bottom areas are under-exposed while the alpine and other high elevation areas are over-exposed. The project might have benefited from a flight using only one film, but with two cameras and two exposures, one for the valley bottoms and another for the alpine and high elevation areas.

Figure A2: Inventory Methodology (Holland et al. 1975)



3. Team Approach

The concepts of a team approach involve an equal and cooperative input from pedologists and vegetation scientists. The team is split between the two Parks, with major input into Banff in the early stages of the inventory and gradual shift of emphasis to Jasper as the project continues. Improvements in the team approach would involve, firstly, a closer and more continuous contact with the geologists, and secondly, the luxury of enough time to become even more involved with site-specific problems and requirements. The site-specific work in which we have been engaged has been one of the better learning and teaching tools encountered to-date.

The advantages of a team approach are gradually becoming more evident. It broadens the work experience and provides interactions that are most useful in development of methodology. Also, the Banff-Jasper team is small enough that field interactions lead to immediate and systematic integration of geology, vegetation, soil, rather than have each discipline go its own way and then attempt integration at the end of the survey. We feel that generalizations made in the field at the time of ground checking are the best way to integrate two or more disciplines.

4. Field and Laboratory Methods

Soil classification and profile descriptions follow the System of soil Classification for Canada (Canada Soil Survey Committee 1970, 1973, 1974). The project is cooperating with, and contributing to CanSIS, the national soil data bank described by Dumanski and Kloosterman (1973). In addition, we are cooperating with CanSIS personnel in developing vegetation data files. CanSIS is assisting the Canadian Wildlife Service in the development of a wildlife data file.

In situ soils data are recorded in the field and quantitative soils analyses are conducted in the soil survey laboratory at the University of Alberta. Methodology is the same as that used in the soil survey of Waterton Lakes National Park (Holland and Coen, in press).

Plant collections are being made by S.Kojima (1975, 1976) and Ian Corns (1976). Nomenclature is based on "Flora of Alberta" (Moss 1959). All specimens are preserved in the Canadian Forestry Service herbarium, Northern Forest Research Centre, Edmonton. Where necessary, specimens will be provided for Parks' herbaria.

APPENDIX B

RESULTS TO-DATE

Area priorities are determined yearly in consultation with Park's personnel. The areas inventories to-date are the more intensive use areas, and include the Bow Valley corridor and Lake Louise area in Banff and in Jasper, the main Athabasca Valley from about Jasper Lake to Sunwapta Falls (See Figures B1 and B2).

Table B1 provides information on data collected to-date.

Table B1: Vegetation and Soil Observations
1975

	<u>Banff</u>	<u>Jasper</u>
No. of veg. plots	587	103
No. of veg. types	29	53
Vascular plant species	505	400
Vascular plant families	55	48
Vascular plants collected	1000	2000
Bryophytes collected	2000	1500
Soil observation points	558	555
Soil laboratory samples	73	64
<i>In situ</i> soil tests	12	-
Notebook records	65	450
CanSIS soil description sheets:		
Daily forms	475	78
Semi-detailed	1	18
Detailed (sampling sites)	11	9
Area surveyed (sq. miles)	600	800
Foot traverse mileage	0	650

The following site-specific work has concerned various members of the biophysical team during 1975:

1. Rehabilitation guidelines for Lakes Edith and Annette area, Jasper (Bull *et al.* 1975).
2. Lake Louise Special Study Area, Banff.
3. Environmental impact study, Mt. Kerkeslin campground, Jasper (Trottier *et al.* 1976).
4. Whistler Mountain rockfall, Jasper.
5. Reclamation planting of old highway between Maligne Canyon and Medicine Lake (about 9 mi), Jasper.
6. Twinning of C.P. Railway track in Lake Louise area of Banff National Park.

A separate report and map is being prepared for the Lake Louise area; it is also being used as a pilot test area for CanSIS cartographic file. Interim reports are being prepared for Banff and Jasper, using Itek copies (Alberta Forest Service) of annotated air photos instead of drafted maps.

Some of the results are being utilized almost immediately, or at least within the first year, particularly the site specific work. Results are also required for the various Planning Units recently established throughout the Parks; eg. the Columbia Icefields Planning Unit, the Lake Louise Special Studies Area, etc. To this extent, Parks Planners want our data by September 1 of each year in order that resource analysis and planning functions may be completed by the end of the fiscal year. The complete master planning for the Parks is required at the end of the project.



Figure B1: Area surveyed in Banff in 1975

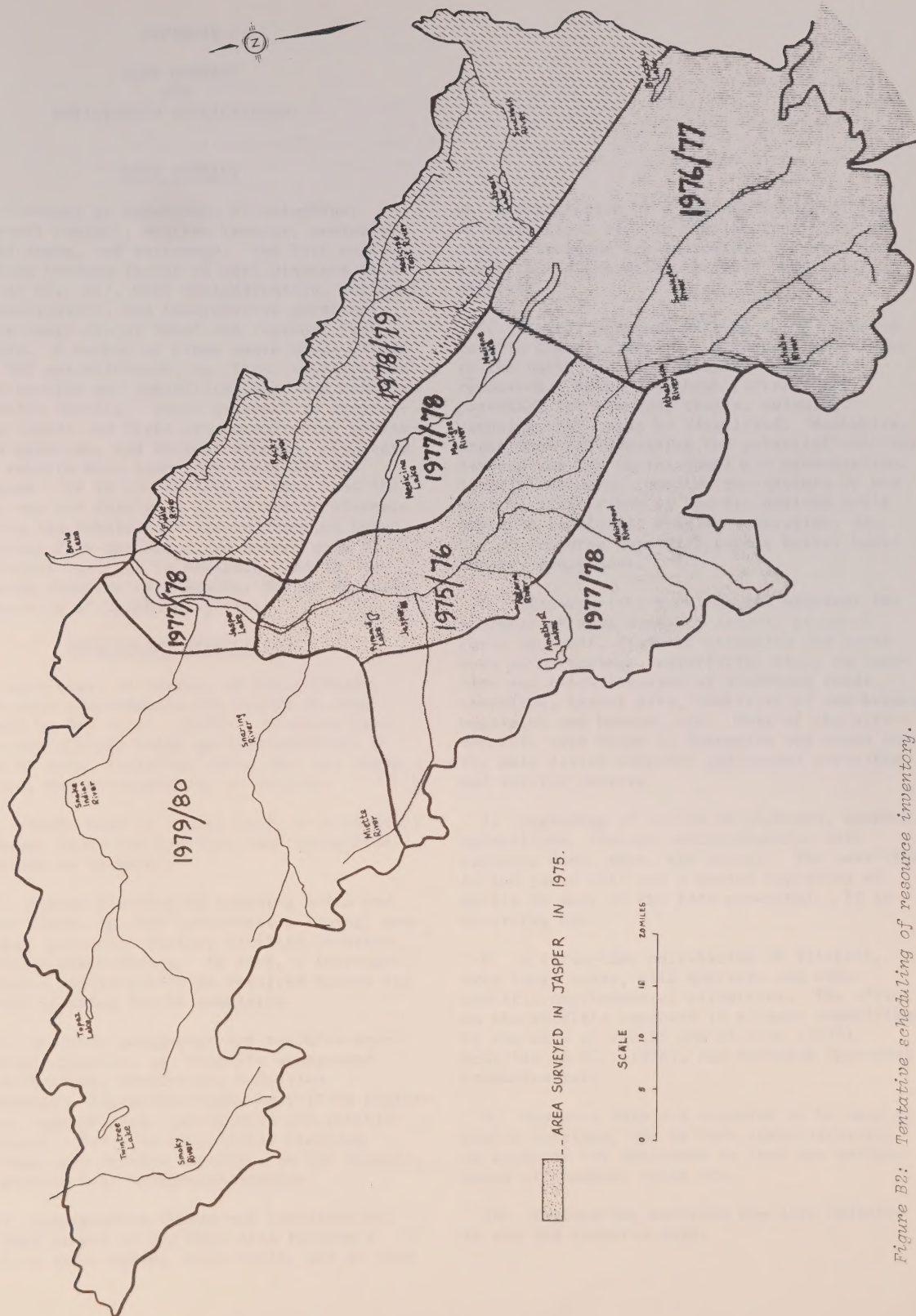


Figure B2: Tentative scheduling of resource inventory.

APPENDIX C

USER CONTACT AND ANTICIPATED APPLICATIONS

USER CONTACT

User contact is excellent; by telephone, personal contact, written reports, seminars, field tours, and workshops. The Park users include various levels of park planners (see top of Fig. A1), park administration, regional administrators, and interpretive personnel. These users are at local and regional Park levels. A number of other users occur within the DOE establishment; eg. fire, regeneration (reclamation and rehabilitation), and Canadian Wildlife Service. Users external to Environment Canada and Parks are consultants, provincial agencies, and various schools. Requests for reports have come from Australia and England. It is interesting to note that the soil map and data used by the master planners during the Public Hearings on Waterton Lakes National Park was displayed before some 45 different agencies in southern Alberta, including Chambers of Commerce, Boards of Trade, University of Lethbridge, etc.

ANTICIPATED APPLICATIONS

The main user, of course, in Parks Canada. Park user requirements are listed in some detail by Day *et al.* (1975). Resource data uses are already being applied; however, a list of uses, including those that are anticipated, may be summarized as follows:

1. Parks want to manage land, or ecological systems; hence the holistic (and integrated) approach to inventory.

2. Master planning of planning units and whole Parks; eg. for conservation zoning, use zoning, potential visitor facility location, resource distribution. In fact, a thorough resource analysis will be required before the master planning can be completed.

3. Resource management and resource operational planning; eg. wildlife management (introduction, protection, reduction censusing), vegetation management (fire protection, regeneration, reclamation and rehabilitation). Resource operational planning becomes very problem specific, as for example, in grizzly bear management studies.

4. Interpretive themes and coordination, so that people in one Park area receive a unified story during their visit, and so that

an interpretation of a certain landform, kind of vegetation, etc. is similar from place to place. Included are audiovisual presentation, exhibits, nature walks, printed pamphlets, or whatever.

5. Visitor services will be using resource data in order to provide wilderness experience to the public while minimizing impact on resources. Areas with high recreational potential for beaches, trails, swimming, canoeing, etc. must be identified. Meanwhile, areas must be identified for potential conflict between use for recreational and preservation. Identification of resource constraints to use must be identified; eg. poorly drained soils, unstable landforms, fragile vegetation, etc. Use of resource data will permit better back-country management.

6. Site-specific problems and studies; the movement of sand dunes in Jasper, study of caves in Banff, study of intensive use areas such as hot springs, waterfalls, etc., reclamation and rehabilitation of abandoned roads, campsites, gravel pits, conflicts of use between ungulates and humans, etc. Most of the site-specific uses occur in intensive use areas in the main valley corridor and around townsites and service centres.

7. Upgrading of skills of planners, wardens, naturalists, through familiarization with resource data, maps, air photos. The next five to ten years will see a marked upgrading of skills by many of the Park personnel. It is occurring now.

8. A first-time correlation of wildlife, over large areas, with habitats and other specific environmental situations. The effect on the wildlife approach is already exemplified by the work of Oertli and Stelfox (1975), McGillis *et al.* (1976), and Karasiuk (personal communication).

9. Resource data are expected to be used at public hearings, and by Park administrators, as evidence for decisions on land use assignments or changes, rules etc.

10. Engineering services are also expected to use the resource data.

Other uses, presently occurring and anticipated include:

1. Demonstration of methodology; the Multiple Land Use Section and other sections of the Alberta Forest Service; Alberta Environment, and some people in the Alberta Oil Sands, Environmental Research Program (AOSERP).

2. A teaching tool; seminars to students in forestry and at agricultural schools,

inclusion in course work at Hinton Forest Technology school.

3. Reference material; requests by schools, various libraries, and individuals.

Certainly the main uses of demonstrated methodology, interpretative uses, and provision of resource data for planning purposes, could be further developed with more time for external contact.

APPENDIX D

PROBLEM AREAS

A broad range of problems exists with varying degrees of intensity of problem. The following is not necessarily in any particular order of priority, nor does it suggest solutions.

1) Acceptance of biophysical terminology:

This, or perhaps the lack of acceptance of terminology by many professionals, including pedologists, causes difficulties in communications. Objections include such items as the use of geographical names for map units. The implication is a weakness in biophysical terminology and definitions, an innate stubbornness in professionals, or a lack of communication between various workers, or a mixture of all three.

2) Differing philosophical approach: There are differences in approach between various professional groups, in particular between the pedologists and vegetation scientists. The pedologist recognizes the mapping problems quite early, develops concepts of modal mapping units, the range and limits of such units, and proceeds with mapping. The vegetation scientist, on the other hand, attempts to sample the entire population before committing any kind of decision. Both approaches have merit, but it does present difficulties with developing and maintaining an integrated biophysical approach.

3) Transfer of knowledge to users: The user audience is extremely variable in its interests and level of training. Thus, we feel strongly about how data are presented; for example, we prefer the use of simple map symbols and an extended legend. However helpful the above techniques may be, they do not solve all of the transfer-of-knowledge problem. We know that the presentation of methodology and resource data must be augmented by interpretative information. Some users possess highly skilled training and require no further assistance with using the inventory data, but others will require very fundamental training before they will be able to use the information. Who is going to provide the necessary training, when, and how?

4) Cartographic problems: Mountainous areas like Banff and Jasper always present problems due to relief and variability of terrain; for example, how does one indicate very small areas of crucial winter range for Rocky Mountain Sheep, when such areas are below the minimum size for symboling, and which virtually disappear when transferred to a planetable map?

Also, correction for photographic distortion is still a problem in transfer of data to maps.

The production of generic interpretative maps by CanSIS has not yet become a reality.

One limitation of the present approach of the biophysical land classification is that the prime objective, which is "to differentiate and classify ecologically significant segments of the land surface" (Lacate 1969), cannot always be met. The biophysical approach emphasizes landform base, which enables the rapid delineation of land units. However, landforms may be rather heterogeneous in terms of vegetation, and conversely, one vegetation type may cover several landforms. Thus, segmentation of the land surface on landform alone is undesirable. Mappable (scale dependent), ecologically distinct (as reflected by vegetation) units upon one landform must be separated. We must recognize the difficulty in mapping apparently homogeneous vegetation units which cross landform boundaries. The recognition and mapping of these instances will be dependent upon the mapper's field experience in the area concerned. Where the mapper is not well-familiarized with the vegetation or in areas which have a lower intensity of 'ground truth' information, mapping units will have a stronger landform base - perhaps an unavoidable situation. A problem thus lies in the recognition and mapping of vegetationally uniform, ecologically significant segments of the land surface where landform boundaries are crossed. To partially alleviate this problem, level 3 of the Banff-Jasper Bio-physical Land Classification System (Table 1) will provide improved continuity of vegetation, at a somewhat generalized level, across landform boundaries.

5) Research requirements: The Banff-Jasper project is an operational one, and as such, does not have the time or funding for some of the background research that now appears to be desirable. We know, for example, that organic matter content of Park soils varies from virtually zero to highly organic, but we do not know what level of organic matter content is optimal for best results for trail location, campsites, or any area receiving intensive human use. We know that alpine soils are different from subalpine soils, but the extent and significance of such differences are not fully known. Some Park land uses, such as large campgrounds (800 - 1000 acres), can be subjected to rotations (an old agricultural custom), but unique areas such as hot springs,

waterfalls, etc., cannot be rotated in a management system, yet must be maintained in an aesthetic state for public consumption. Such unique areas require very site-specific research with regard to rehabilitation and/or maintenance of a favourable environment.

Requirements for rehabilitation of sites have every variation imaginable. Much of the vegetative material, rootstocks, and/or seeds, is not available in sufficient quantities for rehabilitation; for example, few vegetative materials are available for rehabilitation of 40-60 acres of bulldozed ski-runs in a Vegetation Type 8 - alpine larch forest in the Upper Subalpine unit. We know much about horticultural stock and our main forest trees, but lack information on many kinds of plants useful to the mountain Parks.

One of the user requirements, mentioned earlier, was for the identification of resource constraints to Park development. Some, such as slope, or impeded soil drainage, are not too difficult to measure, but others are very difficult. For example, the word 'fragility' is frequently used to refer to sites or vegetation types that are sensitive to disturbance. Firstly, it appears as though an overall 'Environmental fragility index' should be developed along the lines of the following formula:

$$\begin{array}{lcl} \text{Environmental} & & \text{time} \\ \text{fragility} & = & f(\text{soil} + \text{vegetation} + \text{of} + \\ \text{index} & & \text{use} \\ & & \text{intensity} \\ & & \text{of} + \text{wildlife}) \\ & & \text{use} \quad \text{use} \end{array}$$

However, such a 'fragility' index cannot be thoroughly developed until we find out what vegetation parameters need to be measured and how.

Measurement of land response to management is another area of concern.

This paper is not a review of research requirements; however, we do know that there is a need for research.

6) Generalization of map units into a hierarchical classification: How is this best accomplished?

7) Logistic problems: These were discussed earlier under "Operational Methodology", Appendix A. The majority of the easily accessible land in the main corridor is surveyed, so the teams are moving into the backcountry areas but have limited helicopter support. There does not appear to be a fully satisfactory solution to the logistics problem.

8) Determination of user needs: The user requirements are gradually becoming known to the biophysical team; production of resource data and interpretation, plus continued user contact will solve these needs as they occur. No doubt some new requirements will appear before the project is completed.

9) Publications: Reports emanating from the project are in limited quantity, usually four or five copies, except for the Lake Louise Study Area (300 maps printed). This problem will be a difficult one to solve unless budgetary constraints are eased.

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BIOPHYSICAL LAND CLASSIFICATION OF NORTHERN MANITOBA

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ABSTRACT

A systematic biophysical land classification of northern Manitoba was initiated in July, 1974. Development of the system took place over the first year and at present an operational program has completed a field inventory of some 85,500 km² (33,000 mi²). The objective of this land classification is to classify map terrain in terms of land-forms, surface deposits, vegetation, soils, drainage, permafrost, associated aquatic systems and climate. The inventory is designed to provide an ecologically sound basis for making land use decisions concerning forestry, agriculture, recreation, wildlife, community development and hydrology. The methodology for data collection, compilation and presentation is described. An example of the methodology illustrating the hierarchical nature of the system is taken from the Hayes River area in northeastern Manitoba. The strength of this methodology appears to lie in an integrated approach to data presentation enabling a more complete description of the land element of the terrain. Some anticipated uses and limitations of the data, together with estimated costs of the inventory, are presented.

INTRODUCTION

During the last few decades, resource development activities in northern Manitoba have increased to a great extent. Developments in the north are often in the form of large projects; the establishment of Thompson, a community which became in a few years the third largest population centre in the province, and the hydro-electric developments on the Nelson and Churchill Rivers are examples of the kind and magnitude of some recent northern projects. It is apparent that the

RESUME

Une classification biophysique systématique du territoire a débuté en juillet 1974 dans le nord du Manitoba. La première année a été consacrée à la mise au point du système et, jusqu'ici, un programme opérationnel a permis la réalisation d'un inventaire sur une zone de quelque 85,000 km² (33,000 mi²). Cette classification a pour objectif la répartition des terres et l'établissement des cartes compte tenu de diverses caractéristiques telles que le relief, les dépôts de surface, la végétation, la nature des sols, le drainage, le pergélisol, les systèmes aquatiques associés et le climat. Cet inventaire est destiné à servir de fondement environnemental de la prise de décisions concernant l'utilisation des terres dans les domaines des forêts, de l'agriculture, de la récréation, de la faune, de la croissance des communautés et de l'hydrologie. Le document présente une description de la méthodologie de collecte, de compilation et de présentation des données. Un exemple de la méthodologie illustrant la nature hiérarchique de système est donné pour la région de la rivière Hayes, dans le nord-est du Manitoba. La valeur de cette méthodologie semble provenir d'une approche intégrée à la présentation des données, qui rend possible une description plus complète des éléments terrestres des zones étudiées. Le document présente en outre diverses utilisations et limites éventuelles des données, de même qu'une estimation des coûts de l'inventaire.

effects these developments have on the environment and the people in the north will be great. It can be expected that similar projects will be proposed and very likely implemented in the north in the not too distant future.

To be able to plan for future developments, resource use planners require information about the resources and the environment. These requirements will not be the same for

all resource use planners, but will have a common need for some kind of basic information. This information relates to elements in the environment - landforms, climate, soils, permafrost, vegetation, water bodies - that form homogeneous or ecologically significant land units which can be recognized and mapped. Recognizing a need for certain kinds of basic resource data in the planning process, the Manitoba Department of Mines, Resources and Environmental Management initiated the Northern Resource Information Program (NRIP) in 1974.

OBJECTIVE

The purpose of the Northern Resource Information Program is to provide data for resource use planners that will help them plan for the development of natural resources in a way that will benefit all Manitobans. This means generally the provision of data useful for macro scale planning, although the data may be in some instances sufficient for limited micro scale planning. However, because of the reconnaissance nature of the program, usefulness of the data will be greatest when applied at a broad regional level. This means that the data will be useful for planning for the development of renewable and nonrenewable resources on a regional basis; for planning for industrial and community development, the protection of the environment, the development of infrastructure, etc.

During the first year of this program, a system of land classification was developed

for northern Manitoba and a systematic survey initiated. The main objective of this survey is to classify approximately 388,500 km² (150,000 mi²) of Manitoba into ecologically significant land units. A system that classifies land units on such a basis is commonly referred to as a biophysical land classification.

The objective of the present land classification as with numerous other integrated ecological surveys, is to classify and map terrain in terms of landforms and surface deposits, vegetation, soils, drainage, permafrost, associated aquatic systems and climate. Such an inventory will provide an ecologically sound basis for making land use decisions concerning forestry, agriculture, recreation, wildlife, community development and hydrology. The portion of Manitoba for which a biophysical land classification has been requested and the status of work done to date is shown in Figure 1.

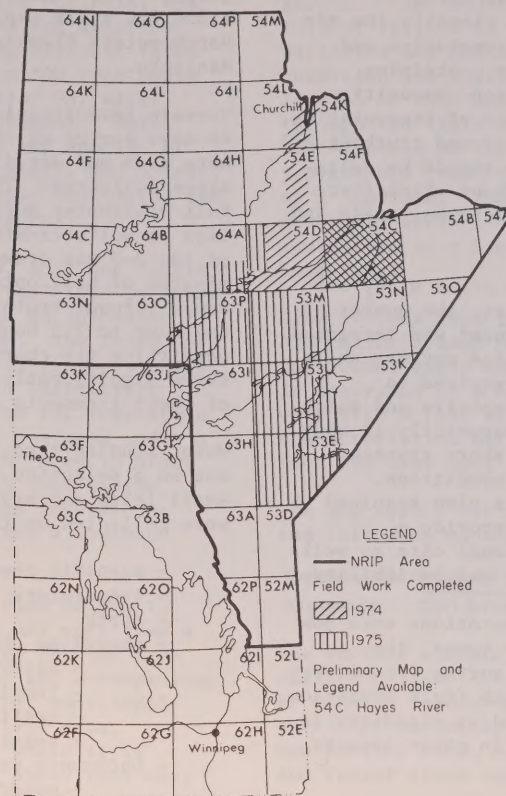
METHODOLOGY

Team Approach - To achieve the objectives established for the biophysical land classification of Manitoba a team approach was chosen. A multidisciplinary team consisting of two people from the staff of the Canada-Manitoba Soil Survey and two people from the Manitoba Department of Mines, Resources and Environmental Management was brought together. In the first year of the program, the team consisted of the following areas of expertise:



Northern Resource Information Program Study Team - 1975. Left to right, front row: J. Clark, H. Morris, S. Forrester, D. Forrester, H. Veldhuis, R. Schmidt, G.F. Mills. Back row: R. Bakowsky, C. Fryer, K. Dutchak.

Figure 1: Location of biophysical land classification projects in Northern Manitoba and status of work done to date.



- senior pedologist - project leader
- forester - pedologist
- wildlife ecologist
- forest ecologist

During the second year of the program, the team was expanded to include a botanist and a resource technician to expedite field operations and to provide input to water body investigations.

A provincial advisory committee was established at the outset of the program to provide leadership and direction for the study team and to promote liaison with users. This advisory group was made up of expertise in the following areas:

- resource planning
- biophysical survey and classification
- remote sensing
- water body classification
- vegetation - wildlife - environment concerns
- data management

- project leader

This group functioned mainly in an advisory capacity during the first year of the program. Contact with users was maintained through the committee and it provided the initial evaluation of available systems for carrying out a biophysical land classification. Once a satisfactory methodology was selected, the advisory role of the group diminished, although it continues to provide liaison and contact with users. In this way, the group helps to determine priority areas in the province where the study team should concentrate its efforts.

Pilot Project - The first year of the program served as a pilot project to develop the system of classification and the method of presenting the data to potential users. It soon became apparent, that to classify and map the large area with which the program was concerned within a reasonable time frame, the amount of ground truthing must be limited and much of the mapping had to be done by means of air

photo interpretation. This in turn, necessitates that the system classify the map patterns of soil, landform, vegetation and water rather than small units containing discrete soil types, vegetation communities, or drainage conditions. Scale of presentation, time frame and intensity of ground truthing all indicated that the land base should be delineated into land units throughout which there is a recurring pattern of landforms, soils and vegetation.

Based on experience from the pilot study and subsequent comments from users, the number of ground truth stops per map sheet was increased. It was felt that 80 to 90 stops per map sheet would provide the coverage required to adequately map the various deposits and soils and vegetation conditions, especially if many of the stops consisted of a short transect describing two or more site conditions. Collection of vegetation data also required some improvement and should provide a floristic list and mensurational data as well as some information on cover and sociability.

Because most of the field operations were now carried out from remote base camps, the logistical component of the survey became very important. To ensure a smooth field operation, the resource technician acted as expeditor in addition to his involvement in other aspects of the program.

The System of Classification (see Appendix I) - Previous work in Canada has led to the establishment of a relatively uniform methodology for carrying out biophysical classifications. After examining some of the approaches taken to terrain classification, the study team decided to utilize a hierarchical system patterned closely after that proposed and defined by Lacate (1969).

DATA COLLECTION, COMPILATION AND PRESENTATION

A realistic evaluation of the data collection phase in the Manitoba program has been made based on the first full field season. However, at present, only a rather cursory evaluation of the data compilation and data presentation phases has been carried out.

Data Collection - In 1975, field studies were carried out from June 12 to September 19. During this period, a biophysical land classification was completed on 62,640 km²

(24,500 mi²) equivalent to 4 1/2 N.T.S. 1:250,000 scale map sheets, mainly in the Northeastern Planning Zone of northern Manitoba.

Terrain investigations in this area required 68 days during which a total of 382 stops were made and detailed information on 567 sites collected. The terrain studies had full helicopter support enabling data collection on soil, landform and vegetation by one or two 2-3 man crews. An average of 35 minutes of helicopter time was expended per stop. Ground truth stops varied from about one hour to 2.5 hours, the longer stops permitting the characterization of two or three significantly different sites by means of short transects of 1 to 2 km.

Water studies throughout the area were carried out on a selection of large, medium-sized and small lakes and several water courses. Data were collected on the following parameters:

- specific conductance
- temperature
- depth
- shoreline characteristics
 - materials
 - length
 - configuration
 - vegetation
- backshore properties
 - materials
 - slope
 - drainage
 - vegetation

An eighteen-second lake survey (Nelson and Faulkner, 1971) using an instrument-equipped helicopter provided data for the first three parameters. The last two items were assessed visually from the helicopter while flying and through examination of the aerial photos in conjunction with terrain studies. A total of nine days in the field and 39 hours of helicopter time was utilized to obtain data on 295 water bodies.

The wildlife biologist on the study team characterized major landform-soil-vegetation associations present in each map sheet in terms of small mammal counts (traplines) and song bird counts (short transects in early morning) and by means of winter aerial surveys for moose and caribou. These data are combined with biophysical relations derived by

other team members to form a basis for identification of wildlife habitat within biophysical map units. The wildlife biologist was also responsible for wetland and waterfowl studies. A small fixed-wing aircraft flown at 70 to 90 m.p.h. and 50 to 300 feet above ground was utilized to examine 987 water bodies (lakes, ponds and streams). Data collected comprised numbers and species of waterfowl, water depth, turbidity and colour, relative abundance of aquatic vegetation and shoreline and backshore features.

Data Compilation - Landform, soil and vegetation data were recorded in the field on forms designed for direct input to an automated storage and retrieval system. The forms for soil and landform characteristics were those developed by the Canada Soil Information System (CanSIS). Field forms for vegetation and water body studies were designed under a similar format as the CanSIS forms in order that they be compatible with that system. Much of the wildlife data was recorded on tape and then transcribed into a longhand format.

The study team has not had time as yet to work with the field data in any more than a preliminary fashion necessary for the production of a biophysical map and accompanying legend. Future plans call for additional effort in the analysis of field data, particularly in those areas where it is possible to be quantitative about land use, hazards to use and productivity for various uses. We realize, in many cases, that analysis of field data and backup research is necessary to become more quantitative and such effort will detract from the map production phase of the overall inventory. However, where demands are for interpretive data for particular uses, the basic biophysical information becomes more viable and has increased value to the user as a result of such studies.

Data Presentation - Although the basic document of the biophysical land classification in Manitoba is a map and legend depicting land systems at a scale of 1:125,000, the interrelationship between pattern of land types and land system is always considered in the context of Land Regions and Districts as well. Region and District boundaries are superimposed on the land system map and a description of their biophysical condition can be attached to the map in tabular form or included in narrative form in an accompanying text.

The boundaries of most map units are based initially on landform and related surface

deposits and delineated on panchromatic black and white 1:60,000 scale air photographs. The landform units are usually further refined in terms of topographic variation and patterns of soils, drainage condition and vegetation. Such characterization of the landform units is accomplished through the field program involving detailed descriptions of the soil, vegetation and topographic conditions on selected portions of a landform. These site descriptions generally apply to a landscape segment equivalent to a Land Type or a complex of Land Types.

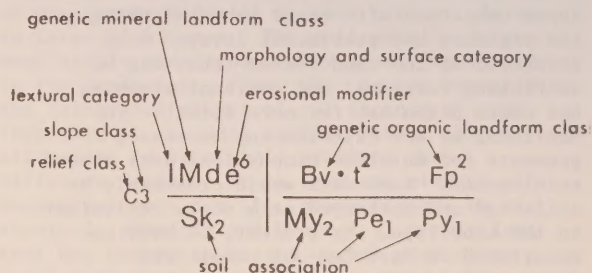
Land systems depicted at the 1:125,000 scale are characterized by a recurring pattern of landforms, soils and vegetation. The unit is described by a map symbol providing the user with a fair account of the land characteristics but for more detailed information the user must consult an extended legend.

The map symbol for a land system is set up in the following manner:

topographic expression	Mineral landforms Soil Association(s)	Organic landforms Soil Association(s)
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The various components of the landscape in a particular land system are described in terms of genetic landform, textural category of the surficial deposits, the kind of morphology and surface form, erosional modifier, slope and relief class and soil association.

Map Symbol:



The soil association symbol directs the user to the expanded legend which will provide information about the land region, parent material, the various soil subgroups belonging to the association, drainage, landscape position of the dominant member of the association, ice content and depth of thaw where permafrost occurs, and the vegetation associated with the dominant soil subgroup.

This approach to data presentation is best described by reference to a map area recently completed in northern Manitoba. The

descriptive material for two land systems from the French River Land District in the Low Subarctic Region as described in the Biophysical Land Classification of the Hayes River area (NTS 54C) is included in Appendix II. In carrying out the classification for this area, the study team had access to surficial geology maps produced by the Geological Survey of Canada (Klassen, R.W. and J.A. Netterville, 1971-74) in addition to data collected from our own ground truth program.

ANTICIPATED USES

Ideally, a biophysical classification such as described in the foregoing section and in the Appendices will serve as an ecological basis for land use planning involving future management of lands for forestry, agriculture, recreation, wildlife, community development and hydrology. Biophysical resource data are also capable of interacting in the planning process concerning alternate land use decisions. Guidelines for terrain sensitivity can be formulated from such data. They can aid in such specific problem solving as delineation of corridors for transportation and pipeline routes.

This hierarchical approach to terrain classification should increase its adaptability to those uses which function at different scales. Land Regions and Districts provide an overview of the extremely complex relations between the biological and physical aspects of the environment. An overview at this scale is possibly of more interest to those concerned with broad macro planning at the regional and provincial level. Data portrayed at the Land System level may be sufficient for local and regional planning but users often ask for more detail. In Manitoba, we are experiencing increased pressure for detailed biophysical data around settlements. Such data would presumably be collected and portrayed at a scale equivalent to the Land Type. At present, we have no experience in carrying out completely integrated terrain surveys at the Land Type level. There are indications that work at this scale tends to become specialized into one or two disciplines, depending on the type of information required. Theoretically, it is possible to portray all terrain and related elements at all levels of detail. It may not be practical, however, to carry out a completely integrated inventory showing all terrain elements at such larger scales.

The degree to which the biophysical classification is successful in meeting user requirements is not the same in all instances.

It varies with the background and expertise of the user, the kind of questions to be asked of the data and in certain cases, our inability to predict precise behavior and response of the environment to manipulation and use. Past experience in dealing with the application of natural resource data to various uses indicates that many user requirements are for interpreted information. The absence of interpretations then becomes a limitation to use of the data. This limitation can be overcome if those involved in carrying out integrated resource surveys plan either to provide an interpretation of their data or be prepared to cooperate with individual users in deriving such interpretations.

Another major limitation to use of biophysical data is the inability of both collectors and users of the data to be as precise as we might wish in predicting behavior and response of the environment under various conditions. This limitation is apparent particularly in northern areas lacking the regional experience and applied research necessary for successful interpretation of that environment. Accumulation of regional experience and inclusion of a certain research element in the data collection phase of the biophysical inventory will help to minimize this limitation.

COSTS

Cost estimates to carry out the 1:125,000 scale biophysical land classification currently being applied in northern Manitoba are based mainly on our experience during the 1975-76 fiscal year. Precise costs are available for a field program lasting 103 days with full helicopter support and operating from remote base camps. These costs, excluding salaries totalled \$121,800 or \$5.00/mi². Field costs including salaries during the field season and a prorated adjustment for developmental costs and capital equipment costs amount to \$6.20/mi².

Exact costs of the professional and technical staff input to the program are more difficult to calculate. Estimates based on professional and technical time expended place total salaries at \$99,000 (based on 3 professional S.M.Y., field and office; 2 technical S.M.Y., laboratory; and the equivalent of 2 technical S.M.Y. field and office). The total cost of the 1975-76 program is therefore \$220,800 (\$121,800 field costs and \$99,000 salaries) or \$9.00/mi². However, one should consider these costs in the context of what the program has produced to date. The Manitoba program has not yet achieved a balanced effort between the data collection phase (field program) and

the data processing and map production phase. This imbalance has resulted in a substantial backlog of map sheets as field work is complete on about 6 1/2 map areas with only one being published to date. A second map area is currently nearing completion.

Wildlife studies utilizing one full professional S.M.Y. also developed a backlog of unpublished information. This backlog resulted in part from the imbalance between data collection and data processing and publication phases. The developmental aspects of the wildlife part of the program further contributed to the backlog. The results of the wildlife studies, which include an interpretation of the biophysical data for wildlife, will appear shortly in a narrative style report pertaining to the first published map area.

Data collected from the water studies have been stored but not brought to any final conclusion either alone or in integrated form with the terrain data. Considerable effort researching this subject was expended by one team member and a preliminary presentation based on an hierarchical ordering of watersheds was developed. Evaluation of this approach has not been attempted as yet.

The level of field activities in 1975, in spite of the allocation of substantial effort to water and wildlife studies, achieved a certain economy and efficiency of scale. However, these efficiencies of operation are lost through inability to adequately process and present the data within a reasonable time frame. Adjustments currently being made in reducing the size of the annual inventory area and increasing the professional input on the data processing and map production phase should help to eliminate the backlog of maps and bring the two phases of the program into balance. These adjustments will also increase the costs of classification per unit area from those experienced during the first two years of operation.

SUMMARY

The nature of land inventories is rapidly changing. Operational biophysical surveys employing multidisciplinary teams of pedologists, ecologists, wildlife biologists and geomorphologists have emerged during the past decade and now make a substantial contribution to resource inventories in Canada. Prior to the advent of biophysical surveys, the Geological Survey of Canada (G.S.C.) and the cooperative Canada Soil Survey were the two main agencies concerned with "surface of the earth inventories".

The G.S.C., since its inception 134 years ago, has carried out a systematic reconnaissance inventory of both bedrock materials and surface deposits over most of Canada's vast land area. Similarly, for some 50 years, the cooperative program of Soil Surveys has played an important role in the inventory of Canada's land resource. The area covered by Soil Survey is about 3,175,635 km² or 1,225,168 mi². This represents about 35% of Canada's total land mass of 9,976,700 km² or 3,800,000 mi². The soil information collected to date does concern most of the settled portions of Canada and provides a very comprehensive assessment of the basic attributes of land. It has become some of the most useful data for much, if not most of the rational land resource planning in Canada.

In this day of comprehensive land use planning, much criticism has been leveled at single discipline or single purpose resource surveys. A single discipline study, by its very nature, is bound to have limitations for satisfying many user needs. In the past, soil surveys have been criticized for the same reason. However, methodology employed by the cooperative soil survey tends to overcome some but not all of the deficiencies of a single discipline survey. This methodology keys on the pedological concept of the soil profile as the basis for inventory. This concept presupposes that similar materials, if occurring under identical environmental conditions of regional and local climate, biological activity, relief, drainage and time, will develop identical soil profiles. It further assumes that similar soil conditions will respond in similar fashion to manipulation or management and will produce similar yields in terms of biomass. The soil profile is the most stable, environmentally sensitive element in the landscape. Thus, the concept recognizes the integrated effect of all factors of soil formation in the soil profile rather than attempting to separately evaluate each different factor. It is this end product, the identified soil profile, characterized by its chemical, physical and biological properties, that has proven to be the useful predictive model representing actual delineated landscape segments.

Recognizing an increasingly wide spectrum of users, and as well, the criticism aimed at single discipline resource studies, the Soil Survey in recent years has broadened its traditional approach to inventory so that ground-truthing, while still emphasising the soil profile, has shifted to include other "land attributes". Data collection is often by a team of specialists who attempt to define map units with greater sophistication and precision largely in terms of additional

data concerning the "land attributes" of the landscape, i.e. landform and vegetative cover. Recognizing this trend, the national Soil Survey recently adopted for its use a modification of the landform classification developed by the Geological Survey of Canada. In addition, individual soil survey groups have established a close working rapport with ecologists and botanists in order to provide a better correlation of soil and vegetation relations. No doubt, part of this shift in direction has come about through pressure on soil survey personnel to become involved in biophysical type inventories across Canada.

Many soil surveys, particularly where a wide spectrum of users is anticipated, attempt as completely as possible, to characterize landscape segments in terms of individual components, soil, landform and vegetation, all integrated within a climatic framework. By means of this approach a soil survey provides a product which is fundamentally the same as that of a biophysical land classification. Such an integrated approach to terrain classification is basic to the biophysical land classification currently being carried out in Manitoba. We retain a strong emphasis on the soil, which as the most stable and environmentally sensitive component of the landscape, is capable of interpretation for a wide range of biological and physical uses. Landform and materials are likewise relatively stable, but biological use interpretation based solely on physical parameters is of limited value when no consideration is given to the effects of regional climate and vegetation on that material. Similarly, vegetation, although sensitive to climatic and certain physical conditions, is relatively unstable and, therefore, cannot be interpreted

consistently for a wide range of uses.

Biophysical land classification, on the other hand, is not a single science, but a group of sciences brought together as a mapping methodology. In Manitoba, we feel that there are advantages to working with an integrated land classification, particularly if the various elements can be ordered hierarchically as under the biophysical approach. The hierarchy enables one to be specific or generalized in depicting the various physical and biological terrain elements. It is possible to show relationships between the various components in the environment at each level of abstraction. In addition, at the Land Region level of abstraction, one is able to synthesize a general climatic framework for distinguishing soil series, the basic building blocks of a soil survey.

In summary, the approach being taken to terrain classification in Manitoba differs only slightly from the standard biophysical survey developed in Canada over the past decade. The main difference lies in a stronger emphasis on soil as compared to that given to other components of the environment. The increased importance attributed to soil is justified because soil is studied and classified as an integration of several environmental factors. Soil, as a relatively stable environmental component, still remains sensitive to the effects of other less stable environmental components. Both approaches, the standard biophysical methodology and the Manitoba approach giving additional weight to soil, provide an integrated resource inventory giving a more complete picture of the biophysical environment than it is possible to obtain from a single discipline resource survey.

APPENDIX I

THE SYSTEM OF CLASSIFICATION AND THE CONCEPT OF LAND REGIONS

Previous work in Canada has led to the establishment of a relatively uniform methodology for carrying out biophysical classifications. A hierarchy of four basic classification units was proposed and defined by Lacate (1969) for the systematic description of terrain:

Land Region - an area of land characterized by a distinctive regional climate as expressed by vegetation.

Land District - an area of land characterized by a distinctive pattern of relief, geology, geomorphology and associated vegetation.

Land System - an area of land throughout which there is a recurring pattern of landforms, soils and vegetation.

Land Type - an area of land on a particular landform segment having a fairly homogeneous combination of soils and chronosequence (i.e. successional development) of vegetation.

The approach taken in Manitoba is patterned after that of Lacate but includes some modification in the definition of the Land Region. All four levels of classification have been used in the Manitoba approach. The basic product of our biophysical classification is a map depicting Land Systems at a scale of 1:125,000. The ground truth and sampling carried out to produce the Land System map is collected at the Land Type level. Land System units, in turn, have been grouped into Land Districts on the basis of general physiographic features. However, Land Districts can also be considered as subdivisions of a Land Region. It is emphasized that the boundaries for Land Districts and Land Regions become really meaningful only after a study of interrelationships in patterns of land types and land systems.

The Land Region - Concepts and Rationale

The concept of Land Region as utilized in the present studies has been broadened somewhat in definition from that given above. Broad regions of uniform climate are identified not only on the basis of vegetation, but also on trends in soil development and permafrost features.

For example, the High Subarctic Land Region

in Manitoba is defined to include those conditions of regional climate which result in a particular pattern of forest cover interspersed with treeless areas of Tundra, i.e. Forest-Tundra transition. This Land Region further exhibits permafrost conditions which are characteristic of the Continuous Permafrost Zone, i.e. depth, distribution and surface expression. The presence of permafrost in the soils of this region is associated with processes and properties which are a consequence of cold temperatures. Climate, and particularly temperature therefore, are major factors governing the development of the soils of this region. Thus, soil development, as it reflects climate, becomes a useful criterion for defining the Region.

The degree of climatic uniformity observable in a Land Region favours the development of similar ecosystems on material having similar properties. For example, similar physiographic sites (i.e. those having the same landform, slope, parent soil material and drainage characteristics) may occur in several climatic regions. Within a region, these sites will support the same vegetation communities, but in other regions vegetation on the sites will be different. Thus, beach ridges in an Arctic Land Region support low growing shrubs and forbs, whereas beaches in the Boreal Region usually have dense growth of black spruce or jack pine. Soils display similar trends, as the kind and development of soil profiles vary from region to region on similar physiographic sites. The depth of the thawed layer, and the form and kind of surface expression of permafrost also vary on similar sites between regions but remain relatively constant on comparable sites within a region (Zoltai, 1973). Land Regions, therefore, describe broad areas where one can expect to find the same kinds of vegetation and soil associations on similar sites.

When considering Land Region differences, one should realize that regional boundaries indicate where significant ecologic changes are taking place, often over a transitional zone. A boundary occurs where change in the climate-soil-vegetation conditions appear to be most pronounced or significant when compared to adjacent areas. A line drawn in this way is only an approximation of where the majority of changes occur and there are many local variations which become obvious when mapping a smaller area in more detail (e.g. an NTS map sheet). For this reason, a particular soil name or vegetation type may be applied in two adjacent Land Regions when site conditions are similar in these regions.

This situation usually occurs only within a limited area on either side of a Land Region boundary; as distance from the boundary line increases, climatic change is sufficient to produce major, significant differences in similar site condition.

An ecological description of extensive land areas must incorporate regional variations in climate; however, climatic information needed to classify such regions does not exist for the most part. In addition, we do not always know which climatic parameters have the greatest influence and are most significant to the ecology of an area or to potential land use developments. Because meteorological data can only show trends or gradients, the critical values or ecological thresholds can only be determined through knowledge of climate-vegetation-soil relationships. Existing climatic data serve only to corroborate to a certain extent the validity of the regional division but cannot define or identify them.

Because climatic change from region to region has such importance to the ecology of an area, the Land Region is useful for establishing soil series and associations. The soils of each Land Region are associated with a range of climatic parameters which influence not only the thermal regime of the soil but also the various biological and physical activities involved in the processes of soil development. Soils developed on similar parent materials and drainage conditions but in different Land Regions are given different names according to the Land Region in which they occur to indicate that many of the associated ecologic conditions are dissimilar.

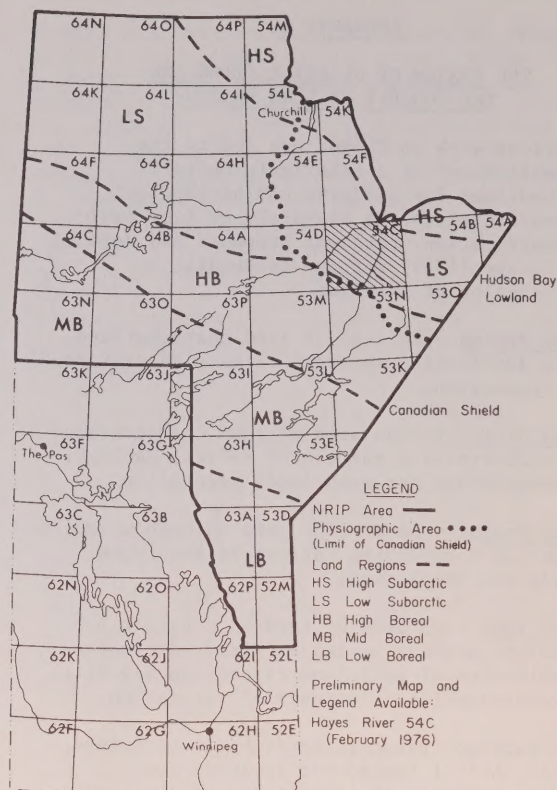
APPENDIX II

EXAMPLE OF INTEGRATED APPROACH TO DATA PRESENTATION

Land Regions - The Hayes River map area contains parts of three Land Regions named from southwest to northeast High Boreal, Low Subarctic and High Subarctic (Figure 2).

The Land Regions shown in Figure 2 are delineated on the basis of dominant soil, vegetation and permafrost conditions occurring over large areas. Because the major changes in dominant soil, vegetation and permafrost conditions of a Region are related to climate, there is an orderly zonation from south to north. Zonation is complicated by the presence of local features such as large water bodies, valleys, extensive organic plains and north-south trending ridges. Some of these features favor development of soil-vegetation

Figure 2: Land Regions in Northern Manitoba



associations typical of adjacent Land Regions. Such atypical "outlier" associations were considered too small or insignificant to be delineated separately, but their presence should be recognized.

The land regions in the Hayes River map area have been described and compared in a tentative summary of their biophysical properties by Mills *et al.* (1976). In this summary, the broad vegetation zonation is after Rowe (1972); permafrost regime has been defined by Brown (1970), and the soil characteristics are derived from exploratory surveys carried out by the Canada-Manitoba Soil Survey. An attempt has been made to describe the stable vegetation according to soil and soil moisture conditions. Local physiographic (site) conditions may change the local climate and hence vegetation development. Such conditions occur on steep south-facing slopes in protected valleys which may make the site warmer, or on north-facing slopes, exposed ridges, snow accumulation areas and in frost pockets, any of which may make the

site colder. Sites which are not so influenced may be called normal or mesic, as the vegetation on them expresses the normal effect of the regional climate (Hills, 1960).

The land district and land systems described in this Appendix are in the Low Subarctic land region. This land region is characterized by open coniferous forest or subarctic forest vegetation. The permafrost is discontinuous and widespread. Dominant soils are Brunisolic Static Cryosols, Brunisols, Luvisols, Gleysolic Static Cryosols and Organo Cryosols. The organic soils occur on peat plateaus, palsas, bog veneers and fens lacking permafrost. Sandy soils are non-frozen, but loams and clays are frozen with an active layer ranging from 30 cm to in excess of 1 m. Cryoturbation is active in lower slopes and depressions but is sporadic in mid and upper slope positions.

Land Districts - Six Land Districts are delineated and described in the Hayes River area; one in the High Subarctic Land Region, four in the Low Subarctic Land Region and one in the High Boreal Land Region. The location of the Land Districts is shown on the Biophysical Land Classification map of the Hayes River area (Mills *et al.*, 1976) and on Figure 3. The two land systems described in detail in the Appendix occur in the French River Land District in the central part of the Low Subarctic Land Region.

The French River land district is mainly an organic plain, with microrelief provided by scattered occurrence of drumlins and abandoned marine beaches. Elevation varies from 120 m along the eastern border to 75 m in the north. The broad U-shaped channel of the Gods River forms a major topographic break in the landscape. This district includes a large cluster of lakes occupying the western 2/3 of the area; the remainder is dominated by organic landforms. The shape of the lakes reflects the topography of the underlying till which is often covered by a thin mantle of marine deposits.

The organic deposits which dominate the District occur in the form of peat plateaus, bog veneers and fens. The peat plateaus are raised, permanently frozen peat landforms; the bog veneers are thin organic accumulations, which contain a sporadic occurrence of permafrost. The fens consist of moderately deep to deep, very poorly drained organic deposits, which contain no permafrost, except in the case of patterned fens. In such cases, frost is found under some of the better developed ridges.

On upland sites and organic peat plateaus and bog veneers Black Spruce forms the stable tree cover; on the better drained ridges, Black Spruce is often replaced by Jack Pine as a result of fire. On bogs, the Black Spruce is associated with *Sphagnum* spp., lichens and ericaceous shrubs. On upland sites the ground cover consists mainly of lichens and/or feathermosses, with minor components of ericaceous shrubs. The vegetation in the fens is dominantly sedges, Bog Bean, Cottongrass and brown mosses, with, in some cases, a stunted tree cover of Tamarack. In the case of patterned fens the ridges are formed by *Sphagnum* spp. and other mosses which support stunted Tamarack and Black Spruce.

Mesic Organo Cryosols are the dominant soils associated with peat plateaus; Terric Mesisols, Terric Mesic Fibrisols usually occur with some Peaty Gleysols in non-frozen parts of the bog veneer areas. Fens are characterized by dominantly Terric and Typic Mesisols formed on fen peat. The active layer in the organic deposits is about 50 cm and ice content of the permanently frozen materials is high. Medium textured till materials are characterized by Eutric Brunisols on the mid and upper slopes and Peaty Gleysols and Gleysolic Static Cryosols in lower slopes and minor depressions. On beach ridges, the dominant soils are Degraded Eutric Brunisols often associated with Gleyed Degraded Eutric Brunisols on the lower slopes.

Land Systems - Part of the biophysical map of the French River land district is reproduced in Figure 4. The landform and vegetation pattern characteristic of different land systems is seen in the aerial photograph of the same area (Figure 5). The following symbols describe two land systems located side by side south of the Gods River. They are:

$$b2 \quad \frac{1Mde^2}{Sl_3} \mid \frac{Bv.t^6 Fp^2}{Dl_2 Pe_1 Py_1} \quad \text{and} \quad \frac{Bt^7}{Pe_1} \frac{Fp^3}{Py_1}$$

$$1. \text{ Land System } b2 \quad \frac{1Mde^2}{Sl_3} \mid \frac{Bv.t^6 Fp^2}{Dl_2 Pe_1 Py_1}$$

This symbol reads as follows:

Twenty percent of the land unit consists of loamy till in the form of drumlins or drumlinoid features, which have been eroded by water. The relief of these landforms is from 3 to 5 meters, with most slopes between 6 and 12 percent. The associated soils belong to

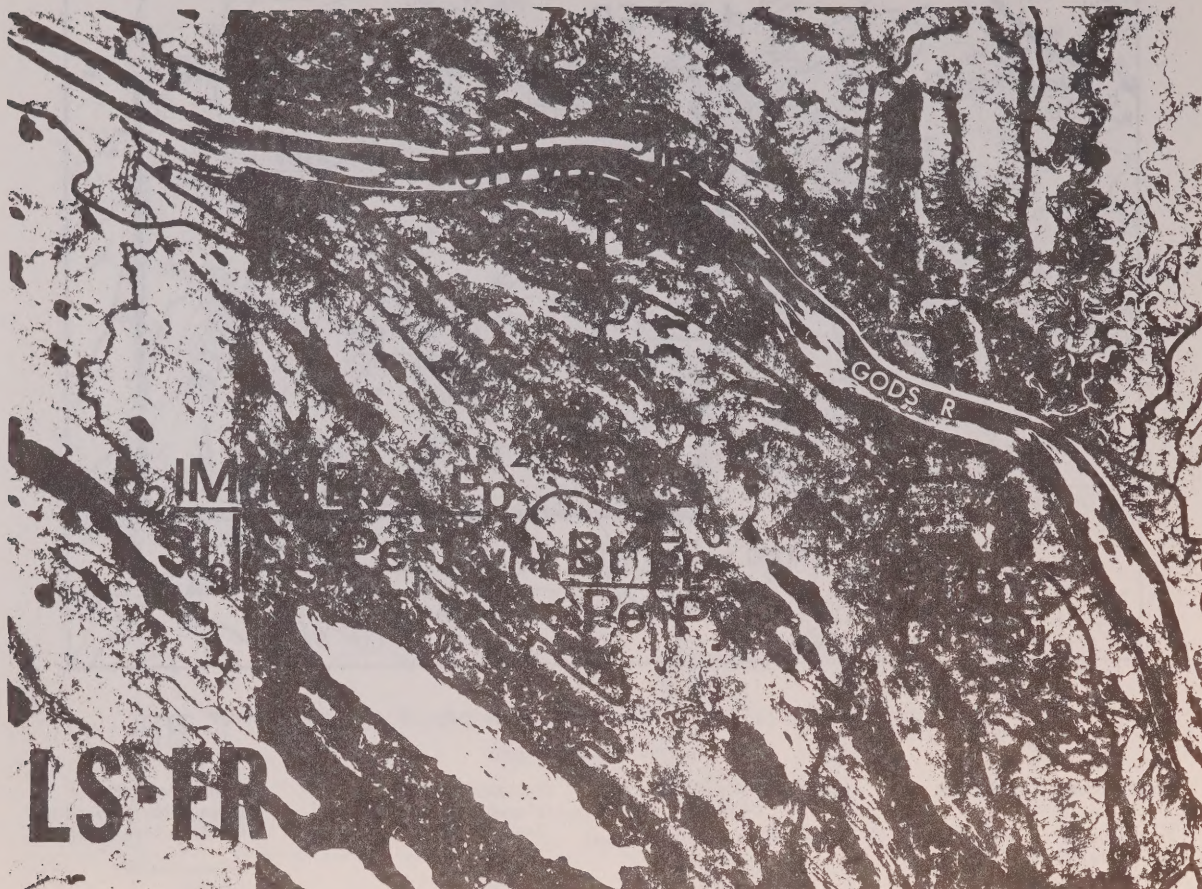


Figure 5: Landform and vegetation patterns of land systems in the French River Land District (see text for descriptions)

Legend for Cartographic Symbols
and Mapping Conventions

MAPPING CONVENTIONS

1. Morphology and surface form categories are applied individually or in combination to the Genetic Mineral Landform or Bedrock Class.
2. Topographic expression applies to both mineral and bedrock landforms and, as well, to shallow organic landforms (box veneer and blanket bog) which reflect the configuration of the underlying material. The topographic characteristics of all other organic landforms are described in the definition of each landform.
3. Map units may be pure or complex:
Pure units consist of one component covering >85 percent of the map unit.
Complex units consist of two or more components, the relative proportion of each being designated in deciles by Arabic numerals placed as superscripts after each landform. The organic landform portion of the map unit is always designated last in the symbol and is separated from mineral and/or bedrock portions by |.
4. Thin veneers or blankets of one geologic material may overly another morphologically dominant unit. Where the overlay is a continuous blanket, the nature of the underlying material is described at the Land District level; if the overlay occurs as a continuous veneer, the underlying materials are described in the definition of the soil association.
5. Areas of dominantly deep organic deposits are designated according to the organic landform only. The underlying materials are described at the Land District level.

CARTOGRAPHIC SYMBOLS

- break of slope (scarp)
- isolated hillock or hummock
- esker (direction of flow assumed, uncertain)
- drumlin or drumlinoid (ice direction shown, not shown)
- moraine ridge
- abandoned strandline
- buried strandline
- meltwater channel
- minor intersecting lineaments or grooves

the Strobilus Lake 3 association.

Sixty percent of the land system is covered by bogs, which are dominantly of the bog veneer type, while the remainder is in the form of peat plateaus. Twenty percent of the land system is covered by patterned fens. The soil associations are respectively Deer Island 2, Pemichagamau 1 and Pennycutaway 1. Using the soil association as a key, additional information can be found in the extended legend (see Table 1).

2. Land System $\frac{Bt^7}{Pe_1} \frac{Fp^3}{Py_1}$

This symbol reads as follows:

The unit consists entirely of organic land-forms in the form of peat plateaus and patterned fens. Approximately 70 percent of the land system consists of raised peat plateaus occurring singly and as complex associations of peat plateau fields. The associated soils belong to the Pemichagamau association. Thirty percent of the land system is covered by patterned fens characterized by the Pennycutaway soils. Utilizing the soil association symbol as an entry to the extended legend, the user can find additional information on depth and physical properties of the soil materials along with drainage characteristics and associated vegetation types.

APPENDIX III

DEFINITION OF TERMS

(Acton, 1975; Tarnocai, 1974; Flint, 1971)

Genetic Mineral Landform Classes -

Alluvial (A). Accumulation of material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Colluvial (C). Accumulation of any loose, heterogeneous and incoherent mass of material or rock fragments (variable mixture of boulder to clay) deposited chiefly by mass-wasting, usually at the base of a steep slope or cliff.

Eolian (E). Accumulation of deposits (sand and silt) whose constituents were transported (blown) and laid down by atmospheric currents, or of deposits produced or eroded by the wind.

Glaciofluvial (G). Pertaining to the outwash deposits and landforms, produced by meltwater

streams associated with and flowing from wasting glacier ice. Such stratified sediments, depending on the depositional environment, are classed as ice contact deposits or outwash sediments.

Ice contact outwash includes kames, eskers and kame moraines deposited upon or immediately adjacent to glacier ice. In addition to a distinctive surface form, ice contact deposits are characterized by extreme range and abrupt changes in grain-size, inclusions of till bodies and marked deformation.

Outwash sediments include stratified materials, mainly well sorted sands and gravels deposited by streams usually in the form of fans, terraces and valley trains.

Glaciolocustrine (L). Materials deposited in glacial lakes; specifically, landforms and deposits composed of suspended materials transported by streams into lakes bordering a glacier which has since disappeared.

Morainal (M). Accumulations of unsorted, unstratified glacial drift, predominantly till, deposited chiefly by the direct action of glacier ice in a variety of landforms that are primarily independent of control by the surface underlying the drift.

Marine (W). Materials deposited in marine environments. These may form a blanket of deeper-water silts and clays, or occur as a series of marine nearshore features composed largely of gravels and sands and deposited as spits, bars and beaches.

Undifferentiated (U). Deposits whose genesis cannot be determined from the available evidence, or mixtures of deposits resulting from the interaction of several genetic processes.

Bedrock Classes

Acidic (aR). Igneous intrusive or extrusive bedrock having more than 66% SiO₂.

Basic (bR). Igneous intrusive or extrusive bedrock having less than 66% SiO₂.

Bedrock (R). A general term for the rock, usually solid, that is exposed or underlies unconsolidated surficial material. Types of bedrock encountered are grouped into "acidic, basic or carbonatic" classes.

Carbonatic (cR). Sedimentary rocks containing large amounts of calcite and other carbonate materials.

Table 1: Portion of the extended legend, Hayes River Map area, 54C Manitoba

LEGEND FOR SOIL AND VEGETATION

Soil Association Symbol	Land Region Name	Parent Material	Map Unit Symbol	Dominant Subgroup ¹	Soil and Drainage ⁴ Significant Subgroup Inclusions ²	Landscape Position ³	Ice Content and Depth of Thaw ³	Dominant Vegetation ^{3, 5}
Df	Deer Island	LS Shallow (40-160 cm) deposits of mesic to humic forest peat with alternating sub-dominant layers of fibric sphagnum peat and/or mesic fen peat underlain by medium to fine textured marine sediments.	Df ₁	Terric Mesic Organo Cryosol (1-p)		Raised peat plateaus and palsas	High; 50 cm	bs-Er-lf-Fm bs-Er-Sp-Fm
Pe	Pemichagamau	LS Deep (>160 cm) deposits of mesic to humic forest peat	Pe ₁	Mesic Organo Cryosol (1-p)	Terric Mesic Organo Cryosol (p-1)	Gently sloping areas with shallow channels, runnels and depressions	Moderate; 50 cm to 100+ cm	bs-Sp-Er bs-Fm-Er-Lf
Pv	Pennycutaway	LS Deep (>160 cm) deposits of mesic fen peat or very thin (15-60 cm) discontinuous fibric sphagnum peat overlying fen peat.	Pv ₁	Typic Mesisol (v)	Typic Mesisol	Raised peat plateaus and palsas	High; 50 cm	bs-Er-lf-Fm bs-Er-Sp
Sl	Strobilus Lake	LS Very strongly calcareous, medium to moderately fine textured stony till.	Sl ₁	Typic Mesisol, sphagnum phase (v) Degraded Eutric Brunisol (w)	Typic Mesisol (v) Orthic Grey Luvisol (w) Gleyed Degraded Eutric Brunisol (d)	Level to depression, water track fens Track to depression, fens Apex and upper slopes	Non-frozen Non-frozen Non-frozen	Cx-Dp-Co tl-Cx-Dp-Sp bs-(jp-tA)-Fm-Al
			Sl ₂	Gleyed Degraded Eutric Brunisol (d)	Rego Gleysol, peaty phase (p) Gleysolic Static Cryosol, peaty ph. (p)	Mid to lower slope	None to moderate; 50 cm to 100+ cm	bs-Fm-Er-Al
			Sl ₃	Rego Gleysol, peaty phase (p)	Gleysolic Static Cryosol, peaty ph. (p) level	Depressional to level	None to high; 50 cm to 100+ cm	bs-Sp-Er-Fm

Notes: 1. Dominant subgroup comprises more than 40 percent of soil association.

2. Significant subgroup inclusions are 20 to 40 percent of soil association. Minor subgroups are listed in order of dominance.

3. Landscape position, ice content, depth of thaw and dominant vegetation refer to the dominant subgroup.

4. Drainage classification

e - excessively drained

w - well drained

i - imperfectly drained

p - poorly drained

v - very poorly drained

5. Vegetation: species abbreviation

Dp - Drepanocladus

bs - black spruce (Picea mariana)

ws - white spruce (Picea glauca)

wb - white birch (Betula papyrifera)

bi - dwarf birch (Betula glandulosa)

tl - tamarack (Larix laricina)

wi - willow (Salix sp.)

al - alder (Alnus sp.)

ta - trembling aspen (Populus tremuloides)

bPo - black poplar (Populus balsamifera)

Cx - Sedge (Carex sp.)

Co - Cottongrass (Eriophorum sp.)

Li - Lichen (Cladonia sp.)

Sp - Sphagnum (Sphagnum sp.)

Er - Ericaceae (Ledum, Chamaedaphne, Kalmia, etc.)

Fm - Feathermosses

jp - Jack Pine (Pinus banksiana)

Undifferentiated (uR). A bedrock material where differentiation into a specific class is impractical or impossible.

Morphology and Surface Form Category

Apron (a). An extensive, continuous, gently sloping and blanket-like deposit of unconsolidated material derived from an identifiable source such as the edge of a large esker or along fault scarps.

Blanket (b). An extensive area of relatively thick (>1 m) surface deposits which subdue but do not completely mask the configuration of the underlying bedrock or deposit.

Delta (Δ). Usually a triangular shaped area composed of stratified materials (ranging from coarse to fine) deposited by streams into large bodies of water.

Drumlinized (d). Elongated, smooth, stream-lined ridges with long axes parallel to the direction of ice movement.

Fan (f). A gently sloping, fan-shaped mass of detritus forming a section of a very shallow cone, commonly at a place where there is a noticeable change in gradient.

Hummocky (h). Terrain having a broken, irregular surface with distinct knobs or mounds and depressions.

Kettled (k). An area of glacial drift pitted with numerous steep-sided, bowl- or basin-shaped depressions that often contain lakes; surface drainage is generally deranged.

Plain (p). An area of comparatively flat, smooth, and level land having few or no prominent surface irregularities, but sometimes having a considerable unit tilt.

Ridged (r). Terrain characterized by long, narrow elevations which may occur independently or in parallel or intersecting patterns. Ridges usually have sharp crests and steep sides.

Rolling (m). Terrain having a smooth, regular surface with broad topographic highs. Slopes are usually 1 km or greater in length.

Terraced (t). A long, narrow, relatively level or gently inclined surface bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope; a large bench or step-like ledge breaking the continuity of a slope.

Undulating (u). Terrain having a smooth, regular surface with broad shallow topographic lows and broad medium to subdued topographic highs. Slopes are usually less than 1 km in length.

Veneer (v). An extensive area of thin (<1 m) unconsolidated surficial deposits which mask little of the configuration of the underlying bedrock or deposits.

Erosional Modifier

Channeled (c). Modification of a deposit or feature by the cutting of channels and removal of material from along local drainage ways.

Deflated (l). Modification by erosive action of wind.

Dissected (i). A network of gullies, ravines, valleys and remnant flat-topped interstream ridges formed by stream erosion acting on a relatively even topographic surface.

Eroded (e). The production or modification of a landform by the action of streams, waves or glaciers.

Washed (w). Landforms which have been modified in some manner by wave action are said to be washed. The process results in the sorting of surface materials or the formation of scattered minor beaches.

Textural Category

Three categories of texture are utilized to describe the nature of the deposits associated with a landform. The texture classes within each category are estimated in terms of size and the distribution of primary particles. Significant inclusions of very coarse particles (gravel, cobbles and boulders) within a deposit are indicated by adding the term "skeletal" as a modifier to the symbol for a textural category.

Primary Particles

<u>Name of Separate</u>	<u>Diameter, mm</u>
Boulders, stones	>250
Cobbles	250-75
Gravel	75-2.0
Very coarse sand	2.0-1.0
Coarse sand	1.0-0.5
Medium sand	0.5-0.25
Fine sand	0.25-0.10
Very fine sand	0.10-0.05
Silt	0.05-0.002
Clay	Less than 0.002

Broad Textural Categories

Clayey (c). Material less than 2 mm contains 35% or more clay by weight and particles 2 mm to 25 cm size are less than 35% by volume.

Includes heavy clay loam, heavy silty clay loam, sandy clay, silty clay, clay and heavy clay.

Fragmental (f). Gravel, cobbles and boulders (2 mm to more than 25 cm) containing too little fine materials to fill the spaces larger than 1 mm.

Loamy (l). Material less than 2 mm contains less than 35% clay by weight and includes coarser materials up to very fine sand size. Particles of 2 mm to 25 cm size are less than 35% by volume.

Includes 2 main groups of texture:

- (1) Light (less than 18% clay by weight):
sandy loam, fine sandy loam, loam, very fine sandy loam, loamy very fine sand, loam, silt loam, silt
- (2) Heavy (18-35% clay by weight):
sandy loam, fine sandy loam, loam, very fine sandy loam, silt loam, sandy clay loam, clay loam, silty clay loam

Sandy (s). Material less than 2 mm contains less than 18% clay and more than 70% sand exclusive of loamy very fine sand and very fine sand. Particles of 2 mm to 25 cm size are less than 35% by volume.

Includes sands and loamy sands.

Skeletal (s). Modifies the main textural categories containing more than 35% by volume of particles coarser than 2 mm size.

Genetic Organic Landform Classes and Categories

Bog (B)

A bog is a peat-covered or peat-filled area, generally with a high water table. Since the surface of the peatland is slightly elevated, bogs are either unaffected or partly affected by nutrient-rich groundwaters from the surrounding mineral soils. The groundwater is generally acidic and low in nutrients (ombrotrophic). The dominant peat materials are sphagnum and forest peat, underlain at times by fen peat.

Categories of Bogs

Bog Plateau (Bp). The height of these peat landforms varies from 0.5 to 1 m and is due to greater peat deposition as compared to the surrounding wet fen areas. Bog plateaus are often tear-drop shaped.

Bog Veneer (Bv). This type of bog occurs when a shallow peat (generally 40-100 cm thick) covers slopes and to some degree, depressions and uplands. The surface topography is often micro-hummocky (sphagnum mounds). Permafrost is discontinuous in this type of bog, and most often found in the better developed mounds.

Bowl Bog (Bp). This type of bog has developed in topographic depressions and has a concave peat surface.

Blanket Bog (Bl). This type of bog occurs when peat covers the uplands, slopes and depressions alike up to a considerable degree of slope.

Flat Bog (Bf). This type of bog is a level peatland area having only slight differences in the level of its surface. Irregularities or slopes of the substratum are completely or almost completely masked by the peat deposit.

Palsa (Ba). A mound of peat with a frozen peat and/or mineral core, occurring in water-logged, treeless or sparsely wooded fens. The height of a palsa is generally between 1 and 3 m, while the width is in the order of some tens of meters.

Peat Mound (Bm). Permanently frozen treeless mounds (0.5 to 1 m in diameter and about 30 to 50 cm high) which occur in water saturated fens.

Peat Plateau (Bt). Peat plateaus are associated with permafrost and their height (approximately 1 m) is dominantly due to ice lens formation in the frozen core. Their sizes range from several acres to tens of acres.

Polygonal Peat Plateau (By). These frozen organic landforms resemble peat plateaus as they are elevated about 1 m above the surrounding fen areas. The surface of this type of peat plateau is dominated by a polygonal pattern caused by ice wedge formation. The surface morphology resulting from ice wedge formation is expressed as a network of polygons having high, near level or slightly depressed centers. The outline of each polygon is marked by a polygonal trench often containing a wedge-shaped accumulation of ice.

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BIOPHYSICAL ANALYSIS OF THE YUKON TERRITORY

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INTRODUCTION

During 1975, a broad-scale biophysical analysis of the Yukon Territory was conducted. The objectives of the project included:

- 1) to conduct a biophysical survey of the Yukon Territory at a scale of 1:1,000,000
- 2) to delineate and map broad vegetational, physiographic and climatic zones and major watersheds
- 3) to assist the Yukon Lands and Forest Service in the use and interpretation of biophysical information and provide for staff training as time permits
- 4) to develop an information retrieval system capable of storing and displaying data on resource statistics in metric units.

METHODS

The survey was conducted by a three-man crew, consisting of a plant ecologist, a landform-soils man and a technician with some assistance of a second landform-soils man, employing fixed-wing reconnaissance flights followed by helicopter and automobile stops aided by LANDSAT imagery and physiographic maps. Prior to initiation of field work, tentative units were devised by reproducing available physiographic, climatic, geology, forest regions and glacial history data on base-maps at a scale of 1:1,000,000 and overlaying them. With the aid of LANDSAT imagery, boundaries were placed along lines of coincidence of the background data. Climatic and vegetation data were given the most weight.

A pert chart was devised which indicated the orderly flow of tasks and responsibilities to be completed by a specified time. Similarly, a flight schedule was devised for both fixed-wing and helicopter aircraft with approval from the Yukon Lands and Forest Service, who were providing the aircraft in connection with their protection program. Base for the fixed-wing aircraft was Whitehorse; the helicopters were distributed from Watson Lake, Teslin, Ross River, Whitehorse, Carmacks, Haines Junction, Beaver Creek, Dawson City and Mayo.

Meetings were held discussing approach, priorities, responsibilities and product with representatives from Department of Indian and Northern Affairs (Yukon Lands and Forest Service, Arctic Land Use Research Programme, and Water Rights) and Department of Environment (Pacific Forest Research, Lands Directorate and Forest Management Institute).

In the field, reconnaissance flights were made over most of the southern Yukon. Only one flight north of 65°N latitude was possible, during which stop-points for ground checking were noted. Also, general distribution of vegetation types, landforms and wetland surface features were recorded. These flights were followed by helicopter and road stops at as many points as time and logistics allowed.

At each field observation site, data were recorded on landform, vegetation, physical site parameters, soil and occurrence of frozen material according to a previously devised data sheet. Samples were collected of B horizons, (and occasionally of other horizons), at most sites for laboratory analysis. Collections were made of most plant species.

The unit boundaries were modified periodically in light of ground truthing.

Contact with district and regional officers of the Yukon Lands and Forest Service was maintained throughout the field programme. Their assistance was greatly appreciated for discussing situations pertinent to regions and arranging flights and accommodations.

The information retrieval system was developed independent of the survey work. The system was designed to cover the area south of 64°N latitude, essentially the area included in the report of Gairns (1968) on forest resources. It is capable of portraying the available forest statistics and data according to a Universal Transverse Mercator grid matrix and by management regions as defined by the Yukon Lands and Forest Service. For updating

purposes, the Whitehorse map sheet (105 D) area was used as the primary test area. Ground observations were related to signatures on LANDSAT imagery as portrayed through Image-100 analyses.

RESULTS

Twenty-two ecoregions were recognized for the Yukon Territory (see Map and Legend) through analysis of available information and field survey data. The term *ecoregion* was selected because the units probably do not meet the requirements, in all cases, of Land Regions as defined by Lacate (1969). Rather they are considered to be complexes of Land Regions and Land Districts with a physiographic bias. Primary parameters used for defining the ecoregions were vegetation, climate, landform and frozen soil condition, but time did not permit sufficient ground observations near the boundaries, which necessitated relying on physiographic breaks for placing boundary lines. The northern units were adopted and largely described from the work of Zoltai and Pettapiece (1973) and Hettinger, Janz, and Wein (1973), because no helicopters were available in these areas and roads allowed access to only a very minor portion.

The ecoregions were delineated on a mosaic constructed from LANDSAT imagery at a scale of 1:2,500,000 for publication purposes. The report to accompany the map is near completion.

Six major watershed systems were delineated, although two of these form parts of the Yukon River system and two form part of the Mackenzie River system. Another is the north slope draining directly into the Beaufort Sea, and the other is a small area draining into the Gulf of Alaska.

The information retrieval system is functional, and has been demonstrated, for portraying available forest statistics in metric units south of 64°N latitude. Future expansion of the system to incorporate up-to-date information, fire history and other resource data, to cover the entire Yukon Territory and portray the data according to ecoregions, is anticipated.

DISCUSSION

Approximately 30 man-weeks were spent in the field, working much of the time as two crews. Difficulties in scheduling aircraft, especially helicopter time, were encountered due to weather conditions and incidence of forest fires. Travel distance among bases, along with other commitments for the aircraft, prevented most alterations in flight schedules.

The most adversely affected area was the west-central part of the Yukon Territory where several fires occurred. Consequently, few ground observations were made from helicopters in the vicinity of Dawson City, Mayo and Carmacks. Roads in these areas, as elsewhere, mostly follow rivers, and thus do not permit observations of upland sites.

About \$11,000 were required for field operations, excluding major equipment, salaries and field aircraft time. Assuming a cost of \$250/hr. for fixed wing aircraft and \$350/hr. for helicopter time, approximately \$23,000 was required for aircraft. The cost of the survey then amounts to about \$.16/mi² (\$.06/km²). Realistically, the time spent in planning, literature review, pre- and post-data compilation, preparation of data for presentation, and equipment must be considered, bringing the cost up to about \$.45/mi² (\$.18/km²).

Biophysical mapping of areas the size of the Yukon Territory (207,076 mi², 536,327 km²), and probably considerably smaller areas, should be conducted over a minimum period of two years. This would allow for a familiarization period, for rescheduling flights the second year into areas not surveyed the first year, and for further work in problem areas.

It would also be desirable to have representation of other resource sectors involved with the field work. However, care would be necessary to prevent the field team from becoming too large and cumbersome. Field crews of two members are optimal for logistical reasons, but two or three such crews, each member representing a different discipline, could be set out and periodic coordination meetings arranged. Problems are inevitable with such a procedure, but the final product would be more beneficial.

Contact was maintained throughout the survey with members of the Yukon Lands and Forest Service, one of the principal users. Training programs are anticipated when the final product is made available and as the project continues.

The ecoregion delineation provided a framework within which more detailed analyses of all biophysical sectors, resource research and broad planning and management decisions can be conducted. Integration of these data with the information retrieval system can aid in the definition and interpretation of ecoregions. Utilization of the ecoregion format in this manner will undoubtedly result in boundary modifications so that land regions and land districts can eventually be recognized and delineated.

Future work in the project, beginning in 1976,

will be to concentrate on one ecoregion, initially the Liard River Ecoregion, and delineate land systems. Involvement will be solicited from the Lands, Water and Wildlife sectors so that a broader resource data base can be established.

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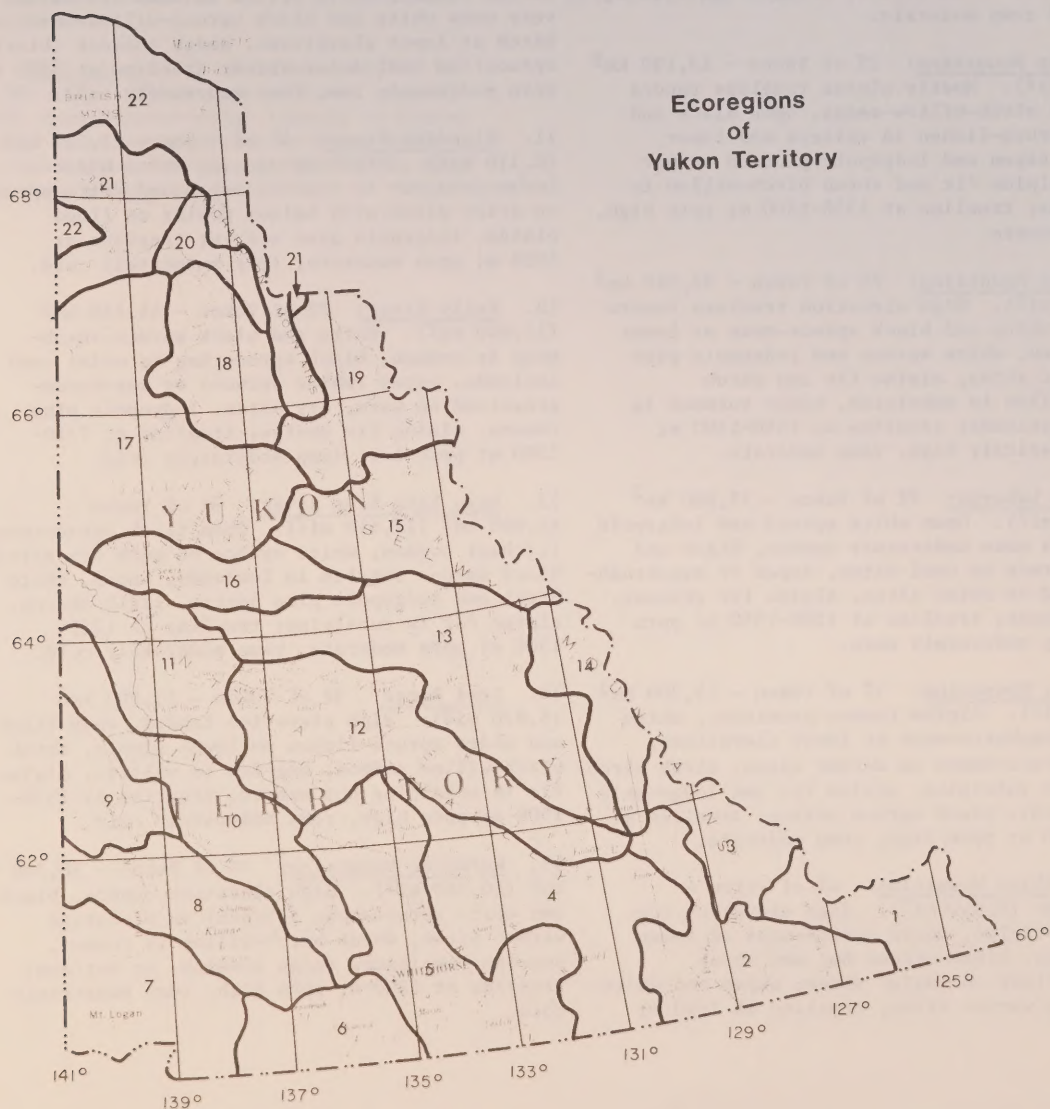
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LEGEND OF ECOREGIONS OF THE YUKON TERRITORY

1. Beaver River: 3% of Yukon - 16,350 km² (6,310 mi²). Mostly forested with open black and white spruce and lodgepole pine; lichens prominent on well-drained sites, moss on wet sites; black spruce and larch in bogs, alpine fir and shrub birch-willow-lichen near treeline; treeline at 1200-1350 m; pptn and temp moderate.

2. Liard River: 5% of Yukon - 24,670 km² (9,520 mi²). Forested, with closed and nearly-closed stands of black and white spruce and lodgepole pine; understory mostly moss with or without shrubs and forbs; black spruce and larch in bogs, aspen on dry sites, white spruce and balsam poplar on flood plains, alpine fire in subalpine; treeline at 1500 m; pptn and temp moderate.

3. Logan Mountains: 2% of Yukon - 13,190 km² (5,090 mi²). Mostly alpine treeless tundra of shrub birch-willow-sedge, open black and white spruce-lichen in valleys and lower slopes, aspen and lodgepole pine on warmer sites, alpine fir and shrub birch-willow in subalpine; treeline at 1350-1500 m; pptn high, temp moderate.

4. Pelly Mountains: 7% of Yukon - 36,140 km² (13,950 mi²). High elevation treeless tundra common, white and black spruce-moss at lower elevations, white spruce and lodgepole pine on warmer sites, alpine fir and shrub birch-willow in subalpine, sedge tussock in alpine wetlands; treeline at 1350-1500 m; pptn moderately high, temp moderate.

5. Lake Laberge: 7% of Yukon - 37,860 km² (14,620 mi²). Open white spruce and lodgepole pine with moss understory common, black and white spruce on cool sites, aspen or sagebrush-grassland on drier sites, alpine fir present, larch absent; treeline at 1200-1350 m; pptn low, temp moderately warm.

6. Coast Mountains: 3% of Yukon - 15,200 km² (5,870 mi²). Alpine tundra prominent, white spruce-soapberry-moss at lower elevations, white spruce-aspen on warmer sites, shrub birch-willow in subalpine, alpine fir and lodgepole pine absent, black spruce scarce; treeline at 1050-1200 m; pptn high, temp moderate.

7. St. Elias Mountains: 4% of Yukon - 22,370 km² (8,640 mi²). High elevation ice and snow fields, white spruce-moss at lower elevations, black spruce bog and shrub birch-willows on cooler sites, aspen and white spruce on warmer sites; treeline at 1050 m;

pptn high, temp cold.

8. Ruby Range: 5% of Yukon - 24,670 km² (9,520 mi²). Open white and black spruce-moss common, black spruce bogs or white birch-alder on cooler sites, white spruce-aspen-moss-forb on warmer sites, lodgepole pine rare; treeline at 1200 m; pptn low, temp moderately cold.

9. Wellesley Lake: 2% of Yukon - 10,900 km² (4,210 mi²). Low elevation open bog, black spruce-*Sphagnum* common, black spruce bog and bog-fen complex on cool moist sites, white spruce-white birch-aspen-moss-alder on warm dry sites, treeline at 1050 m; pptn low, temp moderately cold.

10. Dawson Range: 6% of Yukon - 29,540 km² (11,410 mi²). Mostly treeless, shrub birch-willow common, white spruce on warm dry sites, very open white and black spruce-willow-shrub birch at lower elevations, sedge tussock (black spruce) on cool moist sites; treeline at 1200 m; pptn moderately low, temp moderately cold.

11. Klondike River: 4% of Yukon - 21,510 km² (8,310 mi²). Black spruce and white birch-*Ledum-Sphagnum* is common, aspen and white spruce on drier sites with balsam poplar on flood plains, lodgepole pine scarce; treeline at 1050 m; pptn moderate, temp moderately cold.

12. Pelly River: 7% of Yukon - 45,150 km² (17,640 mi²). White and black spruce-shrub-moss is common, black spruce bog in moist cool lowlands, aspen (white spruce) or sagebrush-grassland on warm, dry sites, lodgepole pine common, alpine fir sparse; treeline at 1350-1500 m; pptn low, temp moderately cold.

13. Mayo Lake Ross River: 9% of Yukon - 45,600 km² (17,610 mi²). Open black spruce-moss (lichen) common, white spruce on warm dry sites, black spruce bog-fen in lowlands, aspen, white birch and lodgepole pine sparse, larch absent, alpine fir in subalpine; treeline at 1350-1500 m; pptn moderate, temp moderately cold.

14. Itsi Range: 3% of Yukon - 15,200 km² (5,870 mi²). High elevation tundra, open black and white spruce-lichen on lower slopes, shrub birch-willow common, bog-fen in valleys, alpine fir in subalpine but sparse; treeline at 1350-1500 m; pptn high, temp moderately cold.

15. Wernecke Mountains: 5% of Yukon - 28,390 km² (10,960 mi²). High elevation tundra, black and white spruce-moss (lichen) on protected warmer sites, shrub birch-willow is common, bog-fen complexes, sedge tussock, in wetland; treeline at 1200 m; pptn high, temp moderately cold.

16. South Ogilvie Mountains: 3% of Yukon - 13,900 km² (5,430 mi²). High elevation treeless tundra, sedge tussock bogs in valleys, and shrub birch-willow on slopes, open black and white spruce on protected warm sites; treeline at 1050 m; pptn moderate, temp moderately cold.

17. North Ogilvie Mountains: 9% of Yukon - 47,040 km² (18,160 mi²). Moderate elevation treeless tundra with sedge tussock or shrub birch-willow, white spruce on protected sites, scattered black spruce in low elevation bogs; treeline at 900 m; pptn moderate, temp cold.

18. Eagle Plain: 3% of Yukon - 17,500 km² (6,760 mi²). Very open black spruce-larch-sedge tussock common, white spruce and white birch on well-drained sites, bog-fen common in lowlands; treeline at 750 m; pptn low, temp cold.

19. Peel River: 4% of Yukon - 20,940 km² (8,080 mi²). Black spruce/lichen common, black spruce-larch-sedge tussock on wetter sites, white spruce-white birch on well-drained sites; treeline at 600-750 m; pptn low, temp moderately cold.

20. Berry Creek: 1% of Yukon - 5,450 km² (2,100 mi²). Black spruce-sedge tussock is common, black spruce-lichen and shrub-lichen on cool dry sites, white spruce on warm sites, larch scarce; treeline at 450 m; pptn low, temp cold.

21. Old Crow Basin: 3% of Yukon - 16,630 km² (6,410 mi²). Open white and black spruce-lichen (moss) common, black spruce-lichen or *Sphagnum* on cooler sites, white spruce-lichen (alder) on warmer sites, larch sparse; treeline at 300-450 m; pptn low, temp cold.

22. Northern Mountains and Coastal Plain: 6% of Yukon - 33,340 km² (12,730 mi²). Mostly treeless tussock tundra, scattered black and white spruce on protected sites, shrub heath on many warmer sites; treeline at 0-300 m; pptn low, temp cold.

BIOPHYSICAL LAND CLASSIFICATION IN THE ENVIRONMENTAL MANAGEMENT SERVICE, DEPARTMENT OF THE ENVIRONMENT

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and

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ABSTRACT

The Department of the Environment (DOE), through the Canada Land Inventory Program and the National Committee on Forest Lands, has supported the development and application of a biophysical classification system for Canada. A summary of the biophysical and related surveys and research is given in this paper. Ongoing as well as planned activities are listed. At present \$1.75 million and about 65 man-years carry out surveys or research directly or indirectly in support of biophysical activities. An Advisory Committee on Northern Baseline Studies was set up in the Environmental Management Service to coordinate baseline studies for the Environmental Assessment and Review Process (EARP).

RESUME

Le ministère de l'Environnement, par l'entremise du Programme d'inventaire des terres du Canada et du Comité national des terres forestières, appuie la création et l'application d'un système de classification biophysique au Canada. La présente communication donne un résumé des études et recherches biophysiques et connexes. Les activités en cours et projetées sont énumérées. A l'heure actuelle, 1.75 millions de dollars et environ 65 années-hommes ont été consacrés à des études ou à des recherches qui appuient directement ou indirectement les activités biophysiques. Un Comité consultatif des études nordiques a été créé au sein du Service de la gestion de l'environnement pour coordonner les études de base dans le cadre du Processus d'évaluation et de révision environnementales (PERE).

INTRODUCTION

The Department of the Environment (DOE), through the Canada Land Inventory (CLI) Program and the National Committee on Forest Lands, has supported the development of a biophysical classification system for Canada. Since the completion of the pilot projects in Québec, Manitoba and British Columbia, this methodology has been applied to various surveys and inventories conducted by DOE. Some of these are described in detail in the Proceedings (e.g. see Zoltai, Oswald and Holland). This paper gives a summary overview of the DOE programs in biophysical and related surveys. The information is based on a report prepared for the Environmental Management Service (EMS) by an interdirectorate committee on Biophysical and Related Surveys, December 1975.

Surveys in the Department were roughly grouped into three types: biophysical, multidisciplinary, and disciplinary (single discipline). These were described as follows:

Biophysical Survey or Inventory - A survey or inventory which is carried out to provide a framework for environmental resource management

and planning using a hierarchical classification system integrating environmental elements (land, water, climate and living organisms). Ecosystems are mapped or grouped and described according to ecological conditions and relationships, usually without direct interpretation and analysis for resource management and planning (i.e. suitability for specific or multiple use). These surveys are usually carried out by an integrated team.

Multidisciplinary Survey or Inventory - A survey or inventory carried out to provide a framework for the management and planning of more than one specific resource to determine the 'best' use within predetermined constraints or concerns. Two or more specific disciplines are involved in a survey using standardized or compatible methodology for classification, evaluation and description.

Disciplinary Survey - A survey or inventory carried out to provide specific data for the management and planning of only one resource.

The activities of each of the EMS Directorates

(Inland Waters, Forestry, Wildlife, and Lands) are listed according to the groups defined above. Only present and planned surveys or studies are included. They are listed by directorate, though in many of them there is participation by other services and government departments. Figure 1 demonstrates, for some of the ongoing survey activities, the relationship between amount of integration (survey methodology) and objectives (as related to the components of the environmental management process).

BIOPHYSICAL SURVEYS

A. In the Lands Directorate:

Coastal Resources Inventory and Mapping Program - A federal/provincial inventory of coastal resources of the Atlantic provinces. This has involved research into the development of a coastal zone classification and pilot projects in Newfoundland for Nova Scotia.

Biophysical Survey of Labrador - In coopera-

tion with the Government of Newfoundland and the Canadian Forestry Service to prepare maps and narratives describing the vegetation and landforms of Labrador.

Biophysical Survey of land potentially affected by Fundy Tidal Power Development.

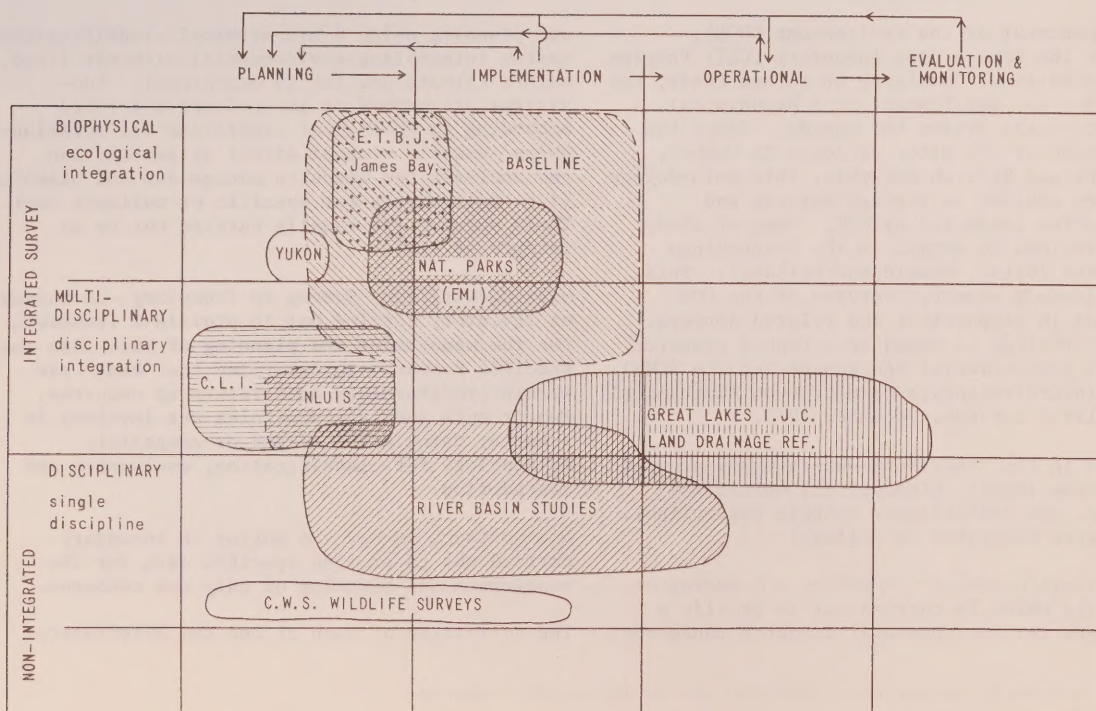
Biophysical Baie James - Involves preparation of maps suitable for interpretation covering the area affected by the James Bay power development. This project includes an evaluation of remote sensing, preparation of a methodology manual, and studies in data presentation.

Biophysical Plaine de St.-Laurent - A biophysical survey similar to the above, carried out in the St. Lawrence Lowlands.

Hudson Bay Lowlands Biophysical Studies.

In collaboration with the Manitoba Northern Resources Inventory Program - Research on the integration of water data into ecological land classification; evaluation of remote

Figure 1



sensing techniques for ecological land classification.

Caribou Range Study - In conjunction with the Department of Supply and Services and other DOE services; provides funding and coordination for a study carried out by the University of Saskatchewan (Dr. J.S. Rowe) on the Caribou Range, N.W.T. This includes biophysical mapping and studies of paleoecology, nutrient cycling and peatland vegetation changes.

B. In the Canadian Forestry Service (CFS):

National Park Biophysical Surveys - In cooperation with the National Parks Service, Department of Indian and Northern Affairs, CFS is carrying out biophysical surveys of several national parks, notably:

L'Anse Aux Meadows (Nfld.)
Kejimikujik (N.S.)
Fundy (N.B.)
Pukaskwa (Ont.)
South Nahanni (N.W.T.)
St. Lawrence Islands (Ont.)
Georgian Bay Islands (Ont.)
Banff-Jasper (Alta.)

These projects include the acquisition and analysis of data, and studies in the presentation of results. An important part of each study is user education, and a number of courses have been held to teach parks personnel how to read and interpret the results.

Avalon Peninsula Biophysical - A cooperative study with the Newfoundland Wildlife Service to prepare a land and ecological capability appraisal and management plan for a provincial park and wilderness area.

Arctic Islands Terrain Project - In cooperation with the Geological Survey of Canada (GSC) to prepare terrain maps along the eastern arctic gas pipeline route.

Yukon Biophysical - To delineate and map broad regional, vegetational, physiographic and climatic zones, and major watersheds.

Environmental Inventories in the Vancouver and Victoria areas - Preparation of a series of maps and narratives on vegetation, soils and recreational features for planning and development.

MULTIDISCIPLINARY SURVEYS

A. In the Lands Directorate:

Canada Land Inventory - Preparation of

capability maps for agriculture, forestry, wildlife, and outdoor recreation, and maps of present land use. The fieldwork is virtually done and effort is presently concentrated on the publication of maps and analysis of the data.

Northern Land Use Information Series - A series of maps prepared for the Department of Indian and Northern Affairs (DINA) to portray critical considerations of social, cultural, and economic features pertaining to land or water use and management. The Canadian Wildlife Service (CWS) and Fisheries and Marine Services (F&MS) participate in this project.

B. In the Canadian Forestry Service (CFS):

Urban Forestry - At present, this survey concentrates on various cooperative programs with the National Capital Commission.

C. In the Inland Waters Directorate (IWD):

Great Lakes Land Drainage Reference Group - A cooperative study with participation by other services and government departments to prepare a report for the International Joint Commission.

River Basin Studies - Surveys and studies to prepare water management plans for a river or lake basin. They entail consideration of a wide range of water-related aspects of the natural and social environments such as economic, recreational, ecological and aesthetic. Study areas include:

Saint John Basin
Souris Basin
Peace-Athabasca Delta
Shubenacadie-Stewiacke Basin
Qu'Appelle Basin
Okanagan Basin
Lake Winnipeg, Churchill and Nelson Rivers
St. Lawrence Water Quality
Churchill River (Sask.)
Athabasca River Basin
Lake Winnipeg Water Quality
Richelieu Valley - in cooperation with Lands and CFS

In addition to the surveys carried out, the various services are carrying out a number of related studies and research projects in support of biophysical classification work. These involve such subjects as development and evaluation of remote sensing classifications and methods, data storage and analysis, and presentation and application of results.

LEVEL OF EFFORT

Advisory Committee on Northern Baseline Studies

In 1976 an Advisory Committee on Northern Baseline Studies was established under chairmanship of the Senior Environmental Advisor. Members are the Regional Environmental Assessment Coordinator and representatives from the Headquarters of each Directorate. The objective of this committee is to coordinate, prioritize and assess the need for Environmental Baseline Studies by EMS. The Committee has defined Environmental Baseline Studies as:

projects undertaken to acquire Environmental Baseline Information which has been defined as a description of environmental properties and processes within a specifically defined area taking into account the dynamic and interactive nature of ecosystems, which will allow the predictions of environmental states resulting from anticipated intrusion by man within a specified time-frame, to meet the requirements of the EARP.

This work is not done in anticipation of any specific kind of environmental intrusion but rather is done so as to provide a basis for the prediction of the consequences of intrusions likely to occur in the area in question.

Biophysical surveys and research are at present largely restricted to Lands and CFS. Current biophysical projects are supported by \$1.5 million and about 48 man-years, about equally divided between Lands and CFS. About a third of this amount is provided by other departments (e.g. National Parks Service of DINA). Research directly in support of biophysical activities (about \$250k and 15 man-years) appears to be carried out predominately by Lands. However, many of the research and survey activities of the CFS in the fields of forest inventory, remote sensing and ecology directly and indirectly play an important role in the further development of biophysical classification methodology. About \$5 million and 140 man-years were required for *multi-disciplinary surveys* in EMS. Major activities include the CLI, the Northern Land Use Information Series (NLUIS), and River Basin Studies. The CLI is in its finalization phase. The NLUIS is an ongoing survey financed primarily by DINA, with DOE involvement from Lands, CWS and F&MS. River Basin studies form the major component of multidisciplinary surveys. IWD is the lead agency, and other DOE Directorates may participate under the coordination of Federal/Provincial Study Boards.

THE USE OF BIOPHYSICAL ANALYSIS IN LAND USE PLANNING*

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ABSTRACT

This paper describes the land use planning process carried out by the interdepartmental Land Use Assignment Committee which advises the Deputy Minister, Alberta Energy and Natural Resources on the allocation of public lands. Biophysical land classification and use potential ratings play a significant part in this planning process together with public land management agency concerns and present land commitments.

The author identifies areas where improvement is required in the planning process as well as the biophysical methodology.

INTRODUCTION

The very real statement that "land is limited but the needs and wants of people are multiplying" is also relevant for Alberta, particularly along the fringe areas of settlement. It could be restated in the vernacular that "quality land is limited and the demands that people are putting on this scarce land resource are unreal".

Alberta recognized this problem in 1948 when an Order-in-Council was passed which identified several major land use concerns. The following points are paraphrased from the 1948 Order-in-Council:

1. It became essential to establish the orderly allocation of lands according to their best use, based on a physical land classification.

2. It became increasingly clear that agricultural settlement should be restricted to lands that were classified as suitable for agricultural development to provide sufficient sustenance for a settler and his family.

RESUME

Le présent document expose le processus de planification de l'utilisation des terres réalisé par le Comité interministériel des terres, qui conseille le ministre albertain de l'Energie et des Ressources Naturelles quant à l'affectation des terres publiques. La classification biophysique du territoire et les cotes du potentiel d'utilisation jouent un rôle important dans ce processus de planification, de même que les intérêts des organismes de gestion des terres publiques et les utilisations actuelles des terres.

L'auteur souligne les aspects à améliorer dans le processus de planification et la méthodologie biophysiques.

3. Since the cost of social services for remote and scattered settlement became increasingly expensive, the government found it necessary to prevent random settlement and squatting in isolated areas.

4. It was recognized that many lands in Alberta had the potential to sustain a valuable forest cover; thus, it was found necessary to prevent land settlement in these areas to allow for the orderly management of forest lands.

Thus, to control land settlement, and for land management purposes, Alberta was divided into three broad areas as follows:

*This paper explains the application of biophysical land analysis carried out by the Land Use Assignment Section of Alberta Energy and Natural Resources (Alta. E&NR) for the Interdepartmental Land Use Assignment Committee (LUAC). Mr. Rennick is Head of the Section.

(a) Green Area - This area comprises lands withdrawn from settlement. Any disposition of the right to use the surface of these public lands is for commercial or industrial purposes, or for such other uses as the Minister may consider to be in the public interest.

Today, much of the Green Area is managed for multiple uses such as timber production, fish and wildlife production, and limited domestic grazing, as well as providing opportunities for outdoor recreation.

The sustaining of a quality environment is a key concern in the area and this is provided for by such means as the *ground rules* implemented by the Alberta Forest Service to ensure watershed protection and to reduce soil erosion during and after timber harvesting operations (Forest Service, Alberta Energy and Natural Resources, 1975).

(b) White Area - This is the settled part of the province. Although much of the land in the area is managed for food production under private ownership, significant portions of public land remain which are managed for watershed protection, outdoor recreation, fish and wildlife production, timber production and other purposes.

(c) Yellow Area - This is where most of the land settlement action is taking place. It is also the area where user conflicts are the most intense. Dispositions such as Homestead Sales for agricultural purposes leading to title may be granted. The Yellow Area will ultimately become part of the White Area, although it will contain public lands reserved for the various public requirements noted in the White Area description.

Figure 1 illustrates the current land settlement pattern in Alberta.

Much credit is due to the authors of the 1948 'Green Area' concept. Although it is not a land 'freeze', by restricting settlement to suitable lands, it allows the government to plan for the optimum use of public land.

The same concerns for efficient and effective land use exist today as they did in 1948. They have merely magnified since more people are exerting greater demands on a limited land resource.

Today, we do, however, have a greater awareness and understanding than we did in 1948, of the ecological factors and the importance that they have in the land use planning process.

This early awareness of land use problems together with the initiation during the 1960's of the ecological approach to land analysis has brought us to our present means of advising the Deputy Minister on the preferred use of public lands.

OUR MEANS FOR LAND ALLOCATION

Resource planning should begin by defining the problem to be resolved. Once this is achieved and the problem understood by the participants, the means for arriving at effective solutions become clear.

As stated above, one of the problems to be solved by the Alberta Department of Energy and Natural Resources (Alta. E&NR) is to achieve within a quality environment the optimum integrated use of public land. This means that for such land uses as timber production, fish and wildlife production, domestic grazing and outdoor recreation, the Alta. E&NR must endeavour to allocate land resources to achieve a compatible mix of these uses.

As we all know, this is indeed a difficult task, due to such factors as the physical limitations of the land, the present land commitments, and the uncertainty of future needs. It is further complicated by the need to provide all of these uses and at the same time maintain a quality environment.

The means for solving this problem, although not crystal clear, involve at least two components. Firstly, we require relevant information on which to base decisions. Secondly, we need to bring together the affected people so that effective solutions may be found.

In 1969, the Alta. E&NR (formerly the Department of Lands and Forests) tackled the second-mentioned component by establishing the inter-departmental and interdisciplinary Land Use Assignment Committee (LUAC) which brings together the appropriate public land managers. We are not so naive to suggest that the LUAC is the ideal structure to solve the problem. However, it does allow for a coordinated approach and provides the means for advising the Minister of Alta. E&NR on the preferred uses of public land.

The first-mentioned component, that of providing relevant information, was provided in part by the establishment of the Land Use Assignment Section, presently located in the Technical Division of Alta. E&NR. The section is made up of an interdisciplinary group of resource specialists who describe, classify, and illustrate for the LUAC the ecological character and use potential of the natural land systems

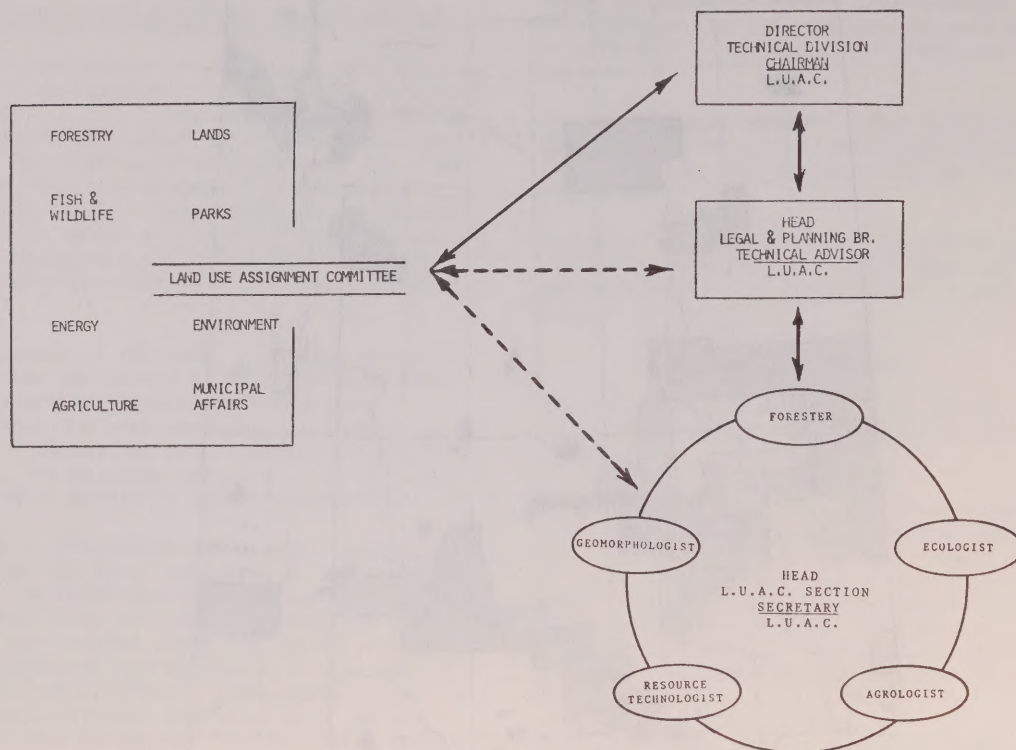
The map displays the province of Alberta, Canada, with its land areas categorized into three settlement status groups. The northern portion of the province is predominantly dark, indicating land available for settlement. The central and southern portions are mostly white, indicating agricultural land not available for homestead sale. A network of black lines, likely representing rivers and major roads, crisscrosses the entire province. The legend in the bottom left corner defines these categories.

Alberta
ENERGY AND
NATURAL RESOURCES

-  Yellow Area - Available for settlement
-  White Area - Agricultural - Not available for Homestead sale
-  Green Area - Withdrawn from settlement

Figure 1

Figure 3: Relationship Between the Land Use Assignment Committee (LUAC) and the Technical Division, Alberta Energy and Natural Resources.



on a mix of uses compatible with the bio-physical analysis and the expressed management concerns.

Consultation - The draft plan is then presented to the concerned parties, such as the local managers, the local Agricultural Development Committee, the Agricultural Service Board and the Regional Planning Commission for their information and to provide an opportunity for them to express their concerns. A method for formal public involvement has not been established, although the LUAC will listen to any public group which asks to be involved.

All of the views expressed during the consultation segment are then considered. The draft may be revised accordingly, and it is delivered to the interdepartmental Conservation and Utilization Committee for their review and comment as to its effect on relevant government

policies.

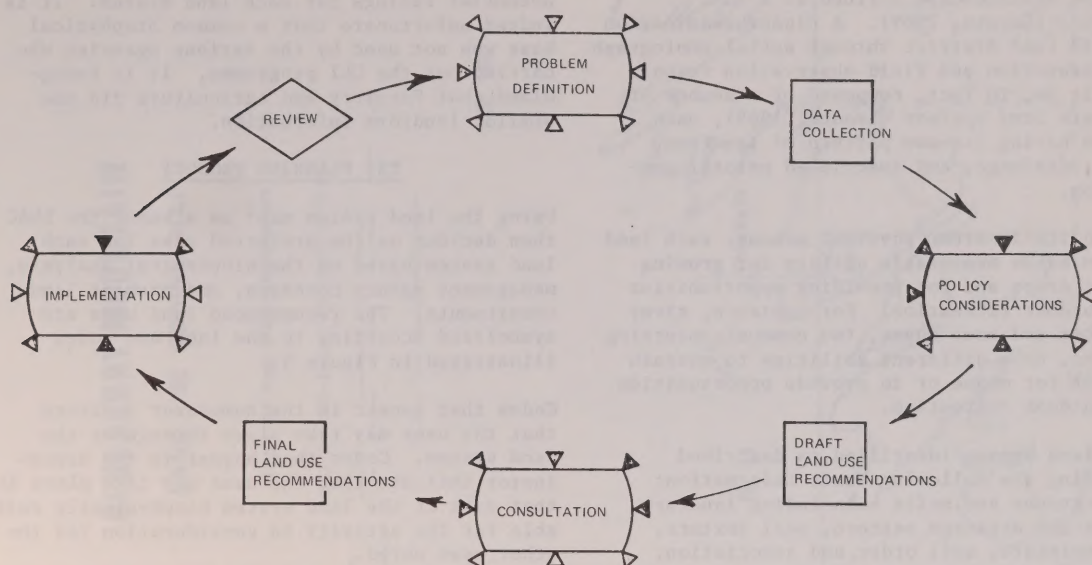
Final Land Use Recommendations - On the basis of the above consultation, the final recommendations are prepared and delivered to the Deputy Minister of Alta. E&NR for his approval.

Implementation - The recommended preferred uses serve to give direction and guidance to the affected Departments for land disposition and land management. The plan also provides a basis for more detailed local management plans.

The information collected and the policies established during this planning process may also be used to guide Regional Planning Commissions and Improvement Districts in the preparation of regional plans.

An important part of implementation is the transferring of approved land use plans into

Figure 4: The Land Use Assignment Committee Planning Process



the Township Registry administered by Lands Division, Alta. E&NR. The natural land unit boundaries are squared off according to the closest legal survey (quarter section) boundary, and the recommended uses for each quarter section are noted.

A four-digit coding system is used to enter all notations and land use reservations in an effort to assure that optimum land allocation takes place.

Review - Each study area is to be reexamined every five years for possible changes in local or regional situations and in light of any new government policies. Preferred uses may then be modified or totally revised to reflect the new circumstances.

THE BIOPHYSICAL METHOD

Based on a four-level planning hierarchy (i.e. Provincial, Regional, Local, and Operational), the level of detail presently carried out by the LUAC approximates a Local land use plan. The published map scale is 1:126,720 which restricts the biophysical detail to the land system level. However, much of the preliminary analysis, including the photo interpretation and the field observations, is carried out at 1:31,600 to better understand the ecological character of the area. Details on

the preliminary maps are then lumped together to form land systems and final maps are reduced to the published scale of 1:126,720.

The biophysical details noted during the analysis are not lost since they are noted in the written description of each land system. They play an important role in the use potential ratings.

The biophysical method employed involves dividing and classifying the landscape into definable ecological land regions, land districts and land systems based on distinctive patterns of relief, geology, geomorphology, landforms, characteristic vegetation and climatic factors as defined by Lacate (1969) and Jurdant (1975).

Existing information such as soil surveys, bedrock geology, surficial geology, and climatic data is collected and synthesized for biophysical relevance.

Considerable emphasis is given to air photo interpretation to delineate distinctive biophysical patterns which reflect the ecological nature of the area. This is achieved by careful observation of landform, slope, drainage and vegetative patterns assisted by knowledge of soils and parent materials.

To illustrate the biophysical method, let us assume that we are dealing with a large expanse of landscape defined as a *land district* (Lacate, 1969). A closer examination of this land district through aerial photograph interpretation and field observation reveals that it is, in fact, composed of a number of separate *land systems* (Lacate, 1969), each system having its own pattern of landform, soils, drainage, and associated natural vegetation.

Due to its inherent physical makeup, each land system has a measurable ability for growing biotic crops and for providing opportunities for outdoor recreation. For instance, river terraces and sand dunes, two commonly occurring systems, have different abilities to sustain habitat for moose or to provide opportunities for outdoor recreation.

Each land system identified is described including the following basic information: physiography and soils - including landform, slopes and drainage pattern, soil texture, soil moisture, soil order and association; natural cover - the major tree species, indicator shrubs and characteristic lesser vegetation; present use - indications of the present cultural practices, amount of cleared land, and management activities; use potential ratings (Hills *et al.*, 1970) - for agriculture, forestry, ungulates, recreation and waterfowl, including a general discussion for the potential of each use.

At the same time, the sensitivity of the landscape to development and surface disturbances is indicated such as observations of soil stability, hazard lands, and important head-water areas.

Once the natural land systems are studied, mapped and described, a report is prepared called "Biophysical Analysis and Evaluation of Capability". The report also includes current information on land dispositions such as patents, leases, licences, agreements and other present land commitments since these are very important considerations in any planning process. The report is then delivered to the LUAC for their information and as a base for the remainder of the planning process.

A comment on the 'use potential rate' methodology is warranted. During the biophysical study, the existing Canada Land Inventory (CLI) capability ratings are used. However, they are 'proportioned' according to Hills' (1970) method to fit the biophysical land system base and they are checked in the field for accuracy. Where questions arise as to a particular rating, the appropriate resource

specialist is contacted for verification. Every effort is made to provide realistic use potential ratings for each land system. It is indeed unfortunate that a common biophysical base was not used by the various agencies who carried out the CLI programme. It is recognized that Forestry and Agriculture did use similar landform information.

THE PLANNING PRODUCT

Using the land system map² as a base, the LUAC then decides on the preferred uses for each land system based on the biophysical analysis, management agency concerns, and present land commitments. The recommended land uses are symbolized according to the land use codes illustrated in Figure 5.

Codes that appear in the numerator indicate that the uses may take place throughout the land system. Codes that appear in the denominator indicate that the uses may take place in that part of the land system biophysically suitable for the activity in consideration for the other uses noted.

When the LUAC completes the land use coding exercise and reaches consensus on the uses, an agreement is prepared advising the Deputy Minister on preferred land uses for the area.

This document contains the purpose of the study, a brief recap of the physical character of the area, the conclusions, and recommendations of the LUAC including the recommended uses for each coded land unit.³ Sensitive areas and nonconforming dispositions are also included as additional information for the concerned managers.

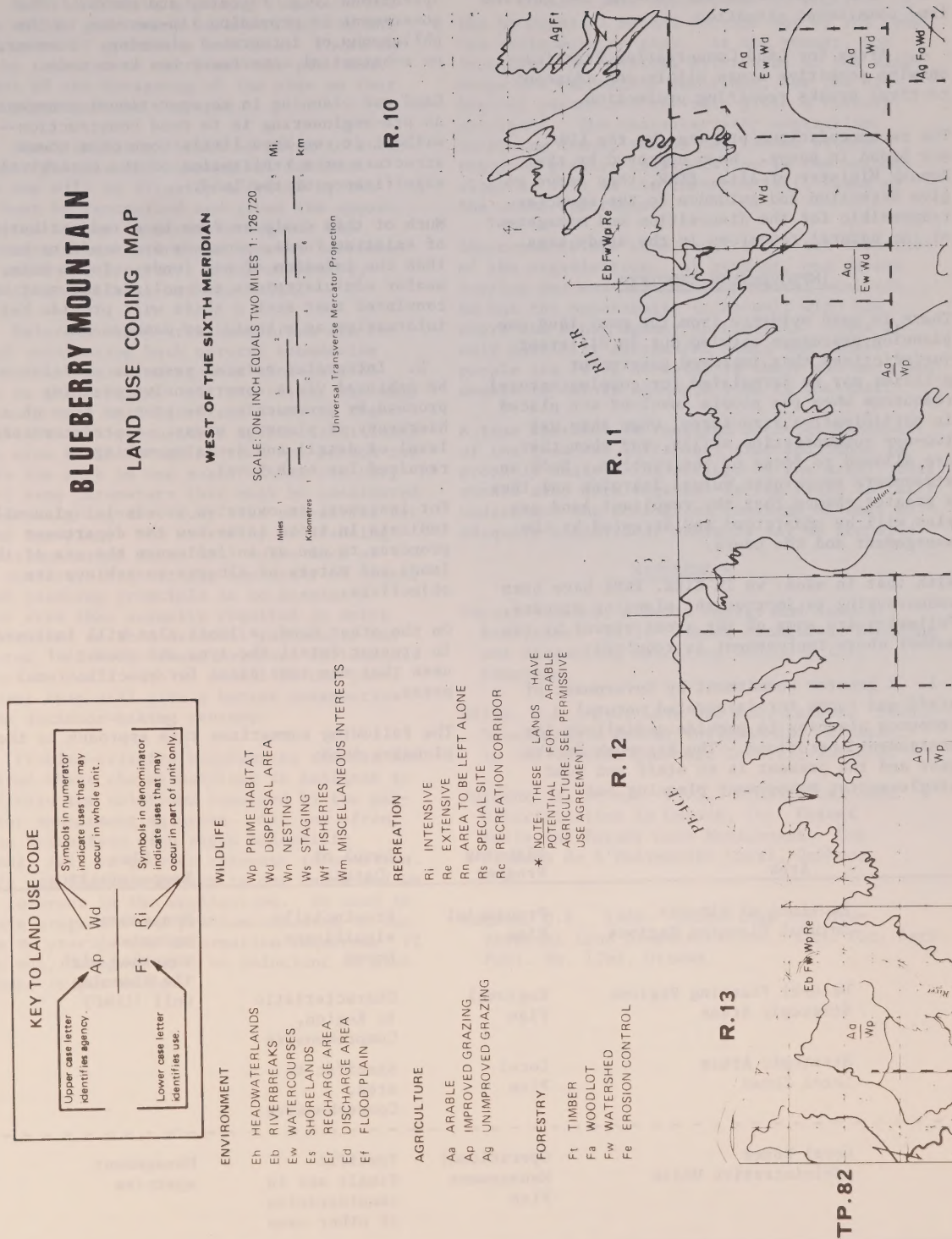
Included with the recommendations are four maps which summarize the preferred uses as follows:

1. Land Use Coding Map showing the preferred uses for each land unit.
2. Permitted Agricultural Use Map showing land units where agricultural practices are allowed as well as the proposed settlement/non-settlement boundary.

2. We call it the Land District Map since it is colour-separated in published form by land districts.

3. The separations on this map can no longer be called 'Land Systems' since land systems given the same codes are joined together into larger land units where the same uses are allowed.

Figure 5



3. Land Disposition Map showing the current land commitment situation.

4. Areas for Land Conservation Practices showing sensitive areas within and adjacent to river breaks requiring protection.

The recommendations prepared by the LUAC are broad in scope. When approved by the Deputy Minister of Alta. E&NR, they serve to give direction and guidance to the agencies responsible for the disposition and management of the natural resources in the study area.

IMPROVEMENTS REQUIRED

There is good evidence from the many land use planning processes carried out in different jurisdictions that improved government policies may be formulated for complex natural resources when the people involved are placed in participative structures, when they use two-way communication skills, and when they are allowed to focus on the problem. Such an atmosphere encourages mutual learning and thus a greater chance that the resultant land use plan will be understood and accepted by the management and the users.

With that in mind, we in Alta. E&NR have been endeavouring to improve the planning process. Following are some of the areas viewed by the author where improvement is required:

1. A greater commitment by Government of staff and funds for integrated natural resource planning to provide guidelines for management operations. The big push in the past and the present is to staff and fund single-sector management planning and

operations (e.g. forestry and parks). The government is providing lip-service to the philosophy of integrated planning. However, no substantial commitment has been made.

Land use planning is to operational management as pre-engineering is to road construction--without it, we have little hope of a sound structure or a realization of the ecological significance of the land.

Much of this could be done by a redistribution of existing funds, programs and staff rather than the infusion of new funds. To do this, senior administrators and politicians must be convinced that such a shift will provide better information as a basis for management.

2. Integrated natural resource policies may be achieved via a comprehensive planning process by approaching the problem through a hierarchy of planning areas. A predetermined level of detail and decision-making is required for each level.

For instance, an overview provincial plan will indicate in broad terms how the department proposes to use or to influence the use of the lands and waters of Alberta to achieve its objectives.

On the other hand, a local plan will indicate in greater detail the type and amount of uses that may take place for specific local areas.

The following summarizes this approach to the planning task:

Area	Planning Product	Level of Detail	Plan Responsibility
Province of Alberta	Provincial Plan	Provincially significant, broad	Management agencies together with the Planning unit (LUAC)
Natural Planning Regions	Regional Plan	Characteristic to Region, Comprehensive	
Natural Planning Regions Strategic Areas	Regional Plan	Characteristic to Region, Comprehensive	
Strategic Areas	Local Plan	Specific to area, Comprehensive	
Local Zones	Local Plan	Specific to area, Comprehensive	
Local Zones	Operational Management Plan	Specific Single use in consideration of other uses	Management agencies
Administrative Units	Operational Management Plan	Specific Single use in consideration of other uses	Management agencies

3. A participative planning structure and style within government is essential for the development of effective policies. Those who will be required to carry out the plan must be part of the designing of the plan so that they understand the concepts.

4. Equal emphasis should be given to socioeconomic factors and biophysical factors. Those who will be directly affected by the plan must be recognized and given the opportunity to become involved throughout the planning process through such means as community awareness programs, group workshops, advisory committees, and the Media.

5. Relevant study area boundaries are required considering both natural boundaries and administrative management concerns, to focus on the problem. All too often, the only rationale used to delineate a study is the possible extent of suitable agricultural lands or an area small enough so that one person can handle the work in one year. These are only two of many parameters that must be considered for establishing the study area boundaries for a land use plan. The hierarchy of planning areas illustrated above will solve much of this concern. Without the hierarchy of areas, a good planning principle is to examine a larger area than actually required to solve the problem, so that external influences may be noted. Although these external influences may not be dealt with in detail in the plan, at least they will give a better perspective to the decision-making process.

6. Problem-oriented biophysical studies are required where the methodology is designed to facilitate the solutions required by the particular management agencies. All too often, we, as scientists with rigid scientific methods, fail to provide relevant information. We are not flexible enough in our means and we lose interest in the application. We need to be more pragmatic and problem-oriented in our means to provide the information required. If we do not, managers will be reluctant to give credence to our trade.

7. Considerable improvement is required in the biophysical method carried out by the Land Use Assignment program. At the moment, for instance, the physical attributes of the landscape are adequately described, but the biological parameters are only given a cursory treatment. The characteristic vegetation, including trees, shrubs and lesser plants, requires greater consideration in the methodology as well as the characteristic fauna of the units described.

Improvements are also required in the structure of the organization. At present, one person carries out most of the biophysical analysis. He has the opportunity to consult with his peers and other agency specialists. This is only partially successful since the other people are fully occupied in their own work and unable to devote adequate time to the task.

A team approach is required where each member of the team has sufficient time and funds to properly analyze the ecology of the area. They should also work together in the field to fully understand the ecological linkages so that an adequate biophysical analysis may be prepared.

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A SUMMARY OF BIOPHYSICAL INVENTORIES, PROPOSALS AND RESEARCH NEEDS FOR SASKATCHEWAN

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INTRODUCTION

There have been no major integrated biophysical or resource inventory programs in Saskatchewan since the completion of the Canada Land Inventory and Pilot Land Use Study. Resource inventories have been completed in specific areas for environmental impact assessments (eg. Churchill River Study, Cluff Lake uranium development, Elizabeth Falls hydro-electric development etc.) and work is underway on an inventory of wildlife habitat in the southern portion of the province.

This paper briefly describes the wildlife habitat inventory program, outlines a proposal of the Department of Northern Saskatchewan (DNS) for biophysical work, and identifies some general concerns and research topics regarding biophysical inventories.

SASKATCHEWAN WILDLIFE HABITAT INVENTORY

A four-phase mapping program of wildlife habitat in the southern portion of the province is being undertaken by the Wildlife Research Unit of the Department of Tourism and Renewable Resources. The work was initiated in 1975, under the supervision of Syd Barber.

The inventory methodology involves the preparation of four overlay maps inventoried and produced on the standard 1:250,000 National Topographic Series Maps. The program has a three year life expectancy at an annual cost of \$50,000. It is estimated that six map sheets will be completed each year.

One of the key maps of the overlay series is biophysical in nature. A classification system of twelve land types has been devised on the basis of soil classifications. These land types are used to determine potential habitat types.

A second overlay map identifies the percentage of land in native grasses and a third identifies land tenure.

These maps together provide the basis for the fourth overlay which, through interpretation of the preceding maps, identifies critical wildlife habitat.

This map series is of a single purpose design that appears, with proper interpretation, to meet the objective of identifying habitat critical to the protection of specific categories of wildlife.

In the portion of the province dominated by agricultural activities it may be a powerful tool in the development of resource allocation policies and management strategies for the protection of wildlife. Nevertheless, the inventory lacks the scope of an integrated biophysical survey; it cannot be interpreted by a wide variety of disciplines and used as a basis for integrated resource planning.

BIOPHYSICAL INVENTORIES AND THE DEPARTMENT OF NORTHERN SASKATCHEWAN

The Department of Northern Saskatchewan is the single agency responsible for the delivery of a majority of programs in the northern portion of the province. The provision of basic services - from health care and education to economic and resource development - falls within its mandate. Given the need for delivery of basic services in the north, land use planning and biophysical inventories have not been seen as high priorities in the initial years of the Department. Nevertheless, the importance of general resource planning is now recognized and a proposal for a lands section within the Department has been made. It is hoped that this work may be initiated in the near future.

Within the lands section there will be a small biophysical inventory group. The coordinator of the biophysical inventory will work closely with the planners and resource managers in the lands section and other agencies during the design of the inventory system to ensure its usefulness and *interpretability* for a number

of disciplines.

The data collection process will remain independent of the planning process (and the planner's bias of interpretation); nevertheless, the system itself will be open to modification on the basis of the usefulness of the information to planners and resource managers. It is in the development of this system that the DNS hopes that the Canada Committee on Ecological (Bio-physical) Land Classification (CCELC) will be of some assistance.

RESEARCH REQUIREMENTS

Several questions that require research are identified below. The first group, related to the economics of biophysical inventories, are questions we often hear and expect from Treasury Board and their analysts. The second group are related more generally to the concept of development in the *mid-north* and the role of biophysical inventories and resource planning within the development process.

1. What are the costs and benefits associated with biophysical inventories?

If the province of Saskatchewan is to undertake a biophysical inventory, what can we expect it to cost and more importantly what benefits can we expect? Will the process of decision making be less costly than at present?

A research strategy to answer these questions should include the following components:

(a) Identify the process of resource planning and environmental impact assessment and document the associated costs if biophysical information is not available. This information should be compiled for each of the following development categories:

- transportation,
- mineral exploration and development,
- recreation and tourism,
- fisheries,
- forestry,
- wildlife management,
- community planning, and
- power developments and transmission corridors.

(b) Identify the change in process of resource planning and environmental impact assessment if biophysical information is available and document the cost savings/increases associated with having this information available.

(c) Is it possible to measure the quality of decisions and identify how the quality is affected by having biophysical information available?

(d) If the benefits outweigh the costs, what training programs are required to enable the various disciplines, (e.g. transportation engineers, wildlife managers, etc.) to make effective use of the biophysical information?

2. An assumption that appears to be a part of the rationale for a biophysical inventory is that better resource information will lead to better resource allocation and management decisions. Further, it is assumed that resource allocation and management problems are ultimately technical (i.e. soluble within a scientific framework).

In Northern Saskatchewan there is a concern that biophysical resource inventories and integrated resource planning, while they appear to be part of a rational process to better manage our environment, tend to reduce problems of values and perceptions to an oversimplified technical level.

An example of this process in operation was identified in Bodley (1975). In the Chittagong Hills, Bangladesh, and eleven-man research team prepared a master plan for the integrated development of the area. While this process (described by Webb, 1966) used sophisticated inventory and planning techniques that appear valid to us, the process ignored the conflict between the traditional economic system of the tribal groups of the area and the national economic system. This example brings to question the nature of the relations between *values, technical information, and decision making*. Furthermore, the question of whose objectives are being served (i.e. local, regional, provincial, etc.) by the process of information collection and planning is raised.

The Canadian Council on Rural Development (CCRD) recently prepared a paper on development in the mid-north (CCRD, 1976) that identifies a *locally based development strategy*. This concept can be used as a framework for the evaluation of the relations of biophysical inventories, values, and decision making in the developmental context of the mid-north. The objective of this work should be to identify a role for biophysical inventories and resource planning in the development process and identify a process for undertaking a biophysical program that is consistent with locally based development.

It is suggested that the Lands Directorate of

Environment Canada, under the CCELC, undertake a research program to fill the informational voids identified under 1. above.

In the second area of concern, the CCELC should collaborate with the Lands Directorate, the Department of Regional Economic Expansion (DREE), and the Canadian Council on Rural Development to undertake the required research.

SUMMARY

1. No major integrated biophysical or resource inventory programs have been undertaken in Saskatchewan since the Canada Land Inventory or Pilot Land Use Study.
2. A wildlife habitat inventory program that has a biophysical component is being completed for the southern portion of the province by the Wildlife Research Unit of the Department of Tourism and Renewable Resources.
3. The Department of Northern Saskatchewan is intending to establish a lands section that would have a biophysical inventory unit.
4. It is suggested that:

(a) The Lands Directorate of Environment Canada, under the advice of the CCELC, undertake research on the costs and benefits of biophysical inventories.

(b) The Lands Directorate, DREE, and the Canadian Council on Rural Development jointly sponsor or undertake research to identify a role for biophysical inventories and resource planning in the development process and identify the mechanisms required for a biophysical program consistent with locally based development.

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BIOPHYSICAL LAND CLASSIFICATION IN BOOTHIA PENINSULA AND NORTHEAST KEEWATIN, N.W.T.*

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ABSTRACT

Boothia Peninsula and northeast Keewatin, an area of approximately 64,000 km², were surveyed as part of a biophysical study. The main objective of the survey was to classify, describe and map the arctic terrestrial environment in terms of landforms, unconsolidated deposits, soils, vegetation, permafrost and eco-climate. The information was presented on three levels: the ecoregion, ecodistrict and ecoarea. The definitions of these three levels are given, as are the roles of the major ecosystem components.

A portion of the Pelly Bay West biophysical map is used to illustrate the system. For this area the ecoregion, ecodistrict and ecoareas are described in detail. Field data, analyses and cost estimate of the project are also given.

RESUME

La presqu'île de Boothia et le nord-est du district de Keewatin, une région de quelques 64,000 km², ont fait l'objet de relevés dans le cadre d'une étude biophysique. L'objectif principal du programme était la description, la classification et la mise en carte du milieu terrestre arctique, compte tenu des reliefs, des dépôts non consolidés, des sols, de la végétation, du pergélisol et de l'éco-climat. Les données ont été présentées sur trois plans: l'éco-région, l'éco-district et l'éco-zone. Les définitions de ces trois plans sont données ainsi que les rôles des principaux éléments des écosystèmes.

Une partie de la carte biophysique de la Baie Pelly ouest sert pour illustrer le système. Pour ce secteur, l'éco-région, l'éco-district et l'éco-zone sont décrits en détail. Le document présente en outre des données recueillies sur le terrain, des analyses du projet et des évaluations des coûts du projet.

INTRODUCTION

Boothia Peninsula and the northeast portion of the District of Keewatin (north of latitude 68°N), an area of approximately 64,000 km² (25,000 mi²), were surveyed as part of a biophysical study (see Figure 1).

Initial planning and logistical support for the field operation was provided by the Geological Survey of Canada, Energy, Mines and Resources, Canada (A.N. Boydell, project leader, now with Environment and Land Use Committee Secretariat, Victoria, British Columbia). This agency also provided the geological and geomorphological information for the project. The soil Research Institute (Canada Soil Survey), Agriculture Canada, as a cooperating agency, provided the soil and vegetation information and the delineation of ecoregions and ecodistricts.

are given, an example of the land classification is discussed, and cost estimates and manpower requirements are outlined. Short definitions of the geological, geomorphological, soil and vegetation terms employed in the classification are included in the appendices.

OBJECTIVES

The main objective of this biophysical study was to classify, describe and map the arctic terrestrial environment in terms of landforms, unconsolidated deposits, soils, vegetation, permafrost and eco-climate. This was done

In this paper the objectives and methodology

* Contribution No. S.R.I. 602

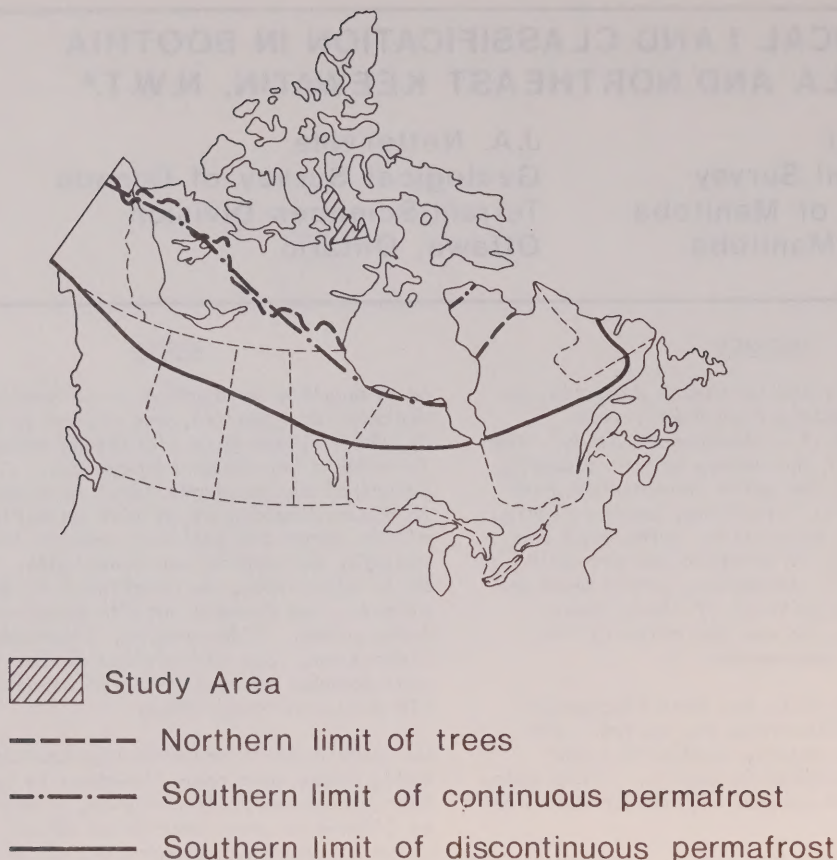


Figure 1. Map indicating the location of the Boothia Peninsula-Northeast Keewatin biophysical study area in the Central Canadian Arctic.

to provide a real knowledge of the physical and biological components of the terrain as background information relevant to land use planning and various aspects of engineering construction, especially to pipeline construction in the area.

METHODOLOGY

Basic Concept - The basic methodology of this biophysical classification is similar to that of previous land classification systems, especially that described by Lacate (1969), and some of the biophysical work carried out in the Mackenzie River area. All of these previous biophysical studies were carried out in the forested regions of Canada, hence some of the terms and definitions used in the Boothia-Northeast Keewatin biophysical mapping project have been modified to fit the

arctic environment.

The biophysical information in this project was presented on three levels: the ecoregion, ecodistrict and ecoarea. All three are interconnected (hierarchical) and ecologically oriented. The landforms and surficial materials provided the basis for mapping on the ecoarea level since they are probably the most stable components of the environment and provide the parent material upon which soils and vegetation develop. Vegetation played an important role in the delineation of climate on the ecoregion level but, since part of the area is sparsely vegetated or unvegetated, other components of the ecosystem, e.g. soils and permafrost (degree of cryoturbation and sorting), provided most of the information. The definitions of ecoregion, ecodistrict and ecoarea, the three basic levels of the system

used in this study, are as follows:

Ecoregion - The ecoregion represents similarities of climate as determined by vegetation, soils and, to some degree, the permafrost condition, which then produce specific eco-systems on material having similar properties (Tarnocai and Boydell, 1975). Ecoregion boundaries were identified through field work and were subsequently mapped using 1:1,000,000 scale LANDSAT imagery.

Ecodistrict - The ecodistrict is a subdivision of the ecoregion and represents similarities of geological, physiographical and geomorphological patterns, soil parent materials and associated ground ice conditions. The ecodistricts in this project were mapped at a 1:250,000 scale and the boundaries were subsequently transferred to the 1:125,000 scale biophysical maps.

Ecoarea - The ecoarea or mapping unit is a recurring pattern of landforms, soils and vegetation. Most of the units mapped in this project are a single landform type, soil association and vegetation cover class with the remainder being composite units developed of two or more landform types. Ecoarea boundaries were mapped on 1:60,000 scale panchromatic aerial photographs and were subsequently transferred to 1:125,000 scale photomosaics and contour maps.

MAJOR ECOSYSTEM COMPONENTS

Eco-climate - An ecologically sound land classification must include the regional variation in climate. The detailed and long-term meteorological information needed to classify the climate in northern areas of Canada does not exist. Even if this information were available we do not now have the information necessary to establish which climatic parameters determine the critical ecological thresholds. This critical ecological threshold value can be estimated, however, through knowledge of the climate-vegetation-soil-permafrost relationships. A degree of climatic uniformity exists in an area (ecoregion) when similar ecosystems (with similar vegetation, genetic soil, cryoturbation, sorting and active layer) develop on similar materials and landform.

Climate is placed at the highest (ecoregion) level in this biophysical land classification. All other levels are arranged according to this climatic framework. For example, a particular soil association occurs only under similar climatic conditions and therefore does not cross ecoregion boundaries.

Surficial Geology and Geomorphology - The system used to map the surficial geology and geomorphology of the Boothia Peninsula and northeast Keewatin is basically the same as that used by the Geological Survey in the forested areas of Labrador, British Columbia, the Mackenzie Valley, central Manitoba, and most recently, in the tundra and 'polar desert' areas of Somerset and Prince of Wales Islands. It has been modified each time as new workers trimmed or expanded certain features within it, attempting to accommodate new problems as they arose. Essentially, the system remains a compromise between the complex landform symboling done in Europe and the systems which utilize simply names or numbers for their units outlining areas of homogeneous terrain or areas exhibiting a characteristic recurring pattern of two or more terrain types. The Australian CSIRO system is an example of the latter.

The Boothia system employs a basic five-part symbol for identification of geologic/geomorphic units. In order of appearance on the interpreted photos, these parts, or descriptors as they are called, are 1) material, 2) origin, 3) morphology, 4) relief and 5) slope. All parts are considered equally important; for ease of interpretation and symbol balance, *material* and *morphology* descriptors are written as lower case letters, *origin* as upper case; arabic numbers indicate *slope* and relief classes, the latter being included as a subscript.

The system is highly flexible. Where necessary, stratigraphic information may be mapped; multiple material and morphologic descriptors may be appended to indicate the presence and relative amounts of each type wherever it is necessary to group them together. If secondary, perhaps relatively recent, perhaps very old, processes have markedly influenced or modified a primary landform, this can be indicated by one or more *morphologic modifiers*. Where a process such as stream aggradation, degradation, or delta deposition is observed to be active, this can be indicated by a map symbol. Where two or more landform units occur in a meaningful, mappable pattern within an area, they may be mapped as a *composite unit* whose constituent relative abundances are indicated on a percentage basis. The system also provides for the mapping of relative abundances of two or more veneer types when they occur in one or both units of a composite unit. Unfortunately, to do all this, the system employs what to some appears to be a rather bulky language base. We feel that the glossary is not unwieldy for a system which apparently can be applied successfully to a

wide variety of terrain conditions, such as those encountered during past programs in which it has been used and developed upon. A listing of the terms used in the Boothia work, or in some cases, the modified terms employed on Somerset and Prince of Wales Islands, is included as a glossary Appendix I, Sections A.1 to A.4.

In addition to the letter and numeric symbols used on the map to denote certain terrain conditions, a small number of schematic symbols are used to indicate the occurrence of specific features whose presence, size, or distribution it is felt necessary to show separately. These special symbols, and their meanings, are also described and illustrated in Appendix I, Section A.5.

To illustrate the system employed during the geologic/geomorphic mapping stage, Figure 2 is included. It consists of a stereopair of a portion of a 1:60,000 panchromatic aerial photograph showing unit boundaries as determined by the geomorphologist. A complete decoding of the unit symbols is given in Table 1. Note that terrain with complex morphological relationships can be visualized from the symbols alone by a person familiar with the system. We feel that by using, where possible, the first letter of each descriptor term as part of the unit symbol, unfamiliar users stand a good chance of successfully utilizing the final maps with very little practice.

Soils - Soils were mapped as soil associations. The soil association is a sequence of soils of about the same age which have developed on parent material of similar origin and physical and chemical characteristics, but having unlike genetic characteristics because of variation in relief and drainage. The soil associations are named after local geographic names. The numbers after the name indicate the change in genetic profile types (sub-groups) or lithological changes within a 1.5 m depth (veneer). Soil associations occur under similar climatic (ecoregion) conditions. Thus, soil association names do not cross ecoregion boundaries. They could occur, however, on similar parent materials in several different ecodistricts within the same ecoregion.

The soil classification used is included in Appendix I, Section B1. The soil parent materials were described on the basis of the origin, texture and CaCO_3 equivalent (see Appendix I, Section B2). Soil drainage classes were also indicated and their description is included in Appendix I, Section B3.

Vegetation - Vegetation communities are named according to the dominant species (see Table 2 and abbreviations in Appendix I, Section C1). In the map legend, the dominant vegetation communities are listed according to the increasing moisture condition within a soil association. On the biophysical map, the vegetation cover class (see Figure 4) is given for each ecoarea.

DATA COLLECTION AND COMPILATION

Field Data Collection - Field data collection was carried out with full helicopter support and also utilized light, all-terrain vehicles and foot traverses. Fixed-wing aircraft (Twin Otter) provided transportation for people, equipment and supplies between the base camp and fly camps.

The study area was covered by helicopter traverses using a Jet Ranger helicopter. Selected stops were made along these traverses and data was collected relating to surficial deposits, geomorphology, soils and vegetation. Soil samples and plant specimens were also collected during these stops. Information, especially that relating to landforms, materials and soils, was also continuously collected from the air during these traverses and this was immediately checked on the previously interpreted 1:60,000 scale panchromatic photographs. Light, all-terrain vehicles were used and foot traverses were conducted in areas where more detailed information was needed. In addition, drilling was carried out at 8 locations (for a total of approximately 14 days) and detailed soil and vegetation studies were carried out on 8 sites (approximately 1 day per site). During the helicopter traverses (approximately 250 hours flying time) 350 stops were made. The foot and all-terrain vehicle traverses covered 60 miles (100 km) and 100 miles (160 km) respectively. These field activities resulted in the collection of 401 soil samples, 68 soil moisture and ice content core samples, 27 carbon dating samples and 150 plant specimens.

Data Analysis and Compilation - Ecoregions and ecodistricts were delineated during the field season and finalized the following winter. Detailed photointerpretation of surficial materials and landforms was also finalized during the winter. Later, the photographs were interpreted for soils and vegetation and changes or modifications in map unit boundaries were made if necessary. The final map unit (ecoarea) symbols were then produced. These symbols included the soil association descriptor

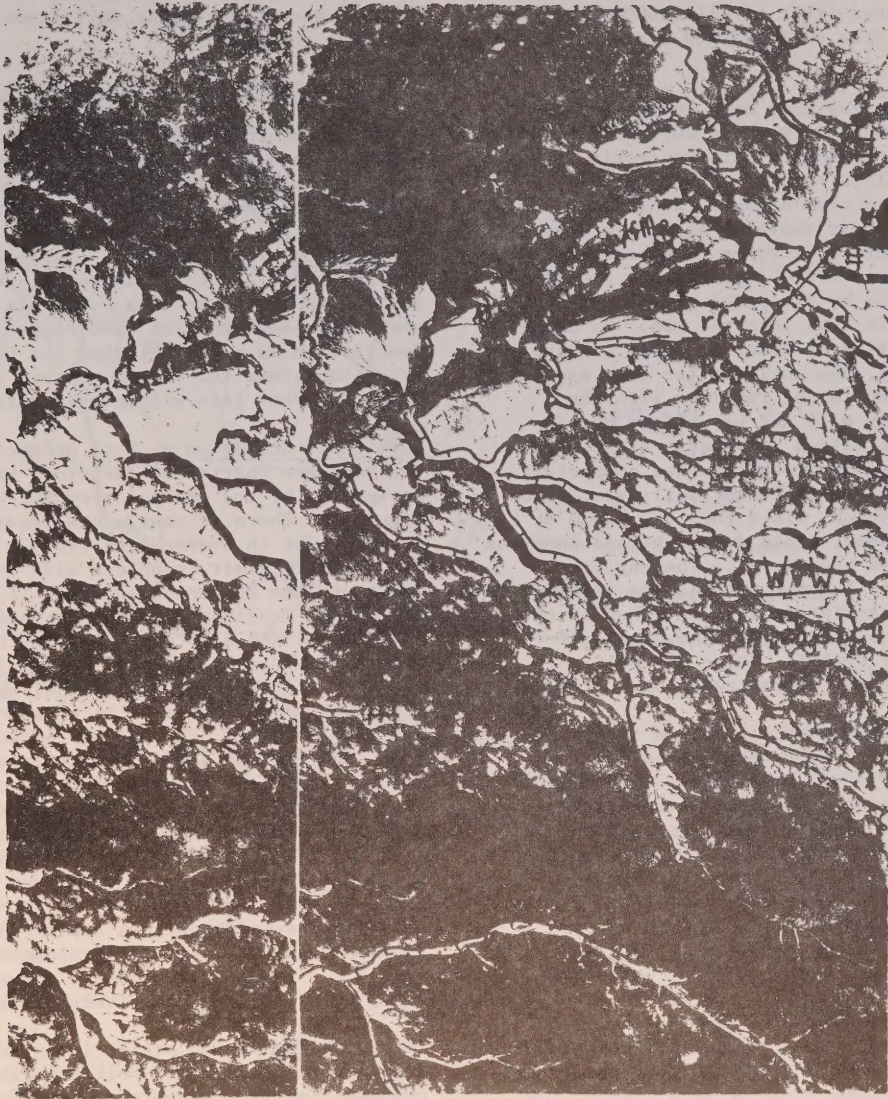


Figure 2: Stereopair illustrating some examples of geologic/geomorphic units. Soil and vegetation data are subsequently integrated into the unit symbols. See Table 1 for a decoding of terrain data contained on this image.

and vegetation cover class in the numerator and the genetic landform, relief and slope designers in the denominator. This information was transferred first to 1:125,000 scale photo mosaics and then to 1:125,000 scale contour maps.

The major changes were made in the original geologic/geomorphic symbols during integration of soil and vegetation data. Firstly, since geomorphologists tend to map texture in terms of grain size classes rather than in soil terms, their textural descriptors were translated into soil terms to become part of the 'soil association' descriptor. This change is made by the pedologist as he integrates his data into the map. By doing this, repetition of descriptors is eliminated. Unfortunately, the engineer (or even another pedologist who is not familiar with the area) probably will not be able to obtain textural information as readily after this change, unless he or she becomes completely familiar with the different soil association descriptors which, since they are based on geographic names, would surely become numerous as large areas are mapped. The engineer would probably benefit most if the original grain size descriptors were retained on the biophysical map as part of the geology/geomorphology symbol. Doing so would not create additional cartographic size problems.

The second major change involves the transfer of stratigraphic information from the surficial geology/geomorphology symbols into the soils legend. The information is keyed to the map through the soil association descriptors which appear in their respective positions in the unit symbols. This move significantly reduces the bulk of the final symbol, thus avoiding creation of a major cartographical size problem. Once again though, unless the engineer is completely familiar with the rather numerous soil association descriptors, he or she must search the soil legend thoroughly to obtain information about covered units in the area, rather than simply read it at a glance from the map. It appears, however, that retention of the original geomorphological descriptors for landforms with an overlying veneer would create major drafting problems at scales involving cartographically small units.

The soil laboratory analysis completed during the winter following field work provided the basis for the separation and description of soil parent materials and for establishing and describing soil associations. The collected plant specimens were identified or the identifications were verified by the

Department of Botany, University of Manitoba Herbarium. Vegetation data were compiled and the major vegetation communities were established according to the soil associations and moisture conditions.

DESCRIPTION OF THE BIOPHYSICAL UNITS

A portion of the Pelly Bay West area (see Figures 3 and 4) was chosen to illustrate this biophysical classification and all detailed information pertains to this area.

Description of Ecoregions - Two ecoregions, the Low-Arctic and the Mid-Arctic, were delineated in the Boothia Peninsula and northeast Keewatin area (see Figure 3). A description is given only for the Low-Arctic ecoregion since the chosen portion of the Pelly Bay West lies within this unit.

Low-Arctic Ecoregion - This ecoregion covers the southern quarter of the study area and is designated by the ecoregion symbol L on Figure 3. There is continuous vegetation cover except on bedrock and eroding surfaces. Its northern limit coincides with the northern limit of some ericaceous species (*Ledum decumbens*, *Vaccinium vitis-idaea* and *V. uliginosum*) and also with that of the tussock-forming *Eriophorum* species. Some willows up to 30 cm high are also present along the river valleys. The soils in this region are dominantly Turbic Cryosols developed on marine silt and clay and sandy loam textured till materials. Minor amounts of Static Cryosols (soils not affected by cryoturbation) which have developed on coarse textured fluvial outwash and marine sand and beach deposits are present. The most common patterned ground types in this ecoregion are the non-sorted circles, ice-wedge polygons and earth hummocks. There is some active peat development in this region but these peat deposits cover only small areas and are relatively shallow.

The thickness of the active layer under various drainage conditions and soil materials is as follows: well to imperfectly drained till, 80 - 90 cm; poorly drained till 40 - 70 cm; well drained sand and gravels, 70 - 80 cm; poorly drained sands and gravels, 40 - 60 cm; imperfectly drained marine silts and clays, 40 - 60 cm; poorly drained marine silts and clays, 30 - 40 cm; well to imperfectly drained alluvium, 60 - 80 cm; and poorly drained alluvium, 30 - 50 cm.

Description of Ecodistricts - The various ecodistricts delineated in the Boothia Peninsula and northeast Keewatin area are designated by an arabic number following

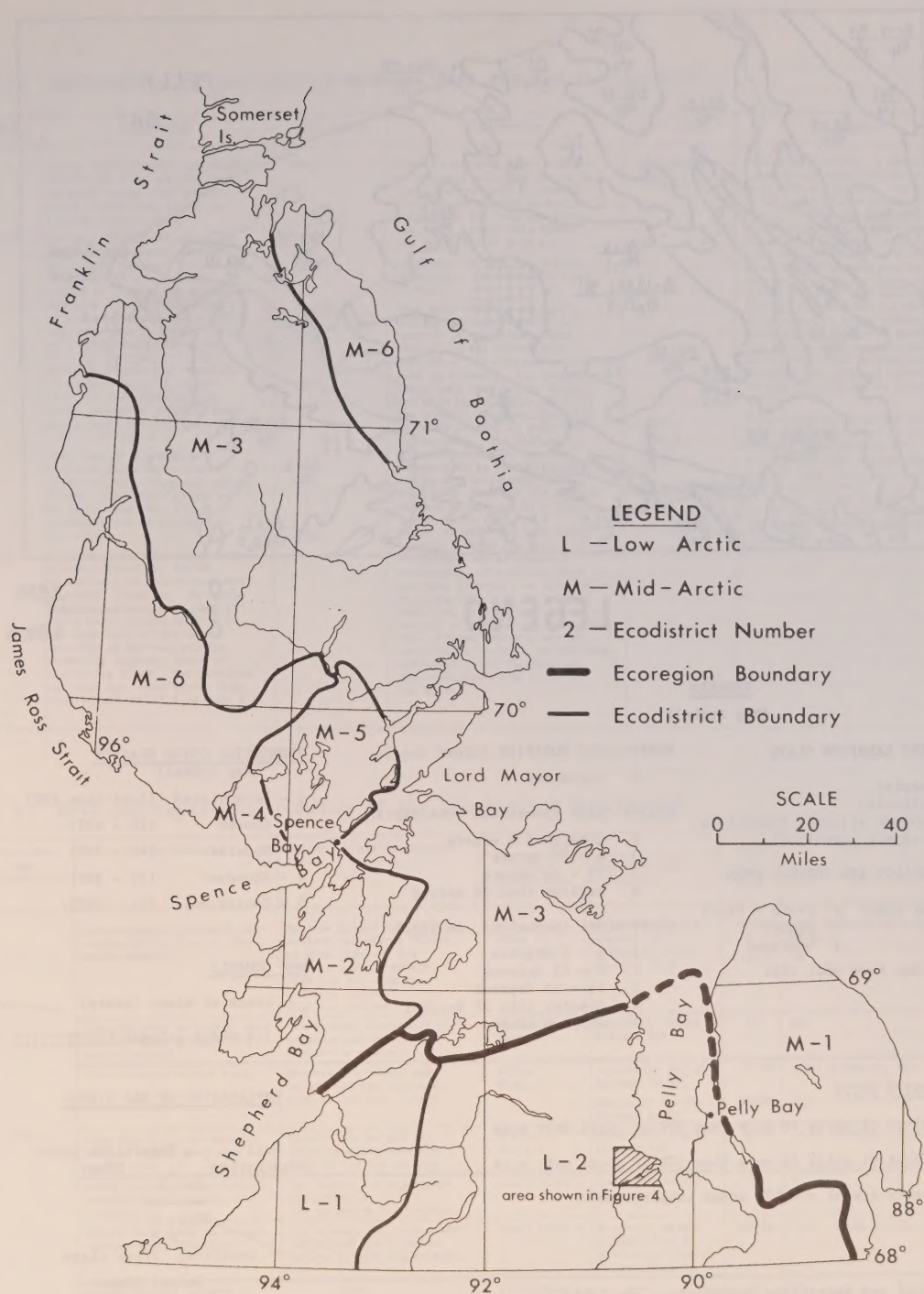


Figure 3. Ecoregions and ecodistricts in the study area. Location of area discussed in text is shown.

Table 1: Explanation of geologic/geomorphic data encoded in Figure 2

Unit Symbol	Explanation	Unit Symbol	Explanation	Unit Symbol	Explanation
fMp ₂ 1	marine plain consisting predominantly of silt and fine sand; regional slope less than 5°, total relief from lowest to highest point 5-20 m.	gAf ₂ 1	These fan-shaped areas consist of alluvial gravel which is in large part subject to annual flooding during the period of snowmelt. The fans are quite low, with slopes less than 5° and total relief 5-20 m.	$\frac{CMWV-grWVW}{CR}$ Rm ₃ 1m ₂ 2	this area consists of gently rolling carbonate and shale bedrock with macroscopic relief of 21-50 m and slopes commonly less than 5°. Superimposed on this gently rolling landscape occur lower bedrock hills (relief 5-20m) with steeper slopes of 6-15°.
gMp ₂ 1r ₁ 1/fMp ₂ 1	at least 80% of the area consists of a gravelly marine plain with regional slope less than 5° and a total relief of 5-20 m. The plain contains a significant number of marine gravel beach ridges less than 5 m in height and with local slopes less than 5°. The remainder of the area (less than 20%) consists of plain areas of marine silt and fine sand. These areas possess a regional slope not greater than 5° and a total relief of 5-20 m.	gAf ₂ 2	As above, but the fan surface is steeper, possessing a slope of 6-15°.		About 60-80% of the area is covered by a veneer (less than 1.5 m) of till; the remainder (20-40% of the area) is covered by a veneer of silty rubble produced by weathering of bedrock. The entire area was once below water. This has to some extent modified the original materials through sorting and/or redeposition.
gAp ₂ 1	this area is a gravelly alluvial plain above the apparent limit of annual spring floods. The plain slopes at an angle less than 5° and possesses not more than 5 m of relief.	$\frac{grWVW}{CR}$ Rm ₄ 1h ₃ D ₂ 4	This area consists of gently rolling carbonate and shale bedrock (average slope less than 5°, total relief more than 50 m). In places the bedrock is hummocky, the hummocks being less than 5 m in height but with steep slopes of 16-35°. The bedrock has been dissected by water erosion at some time in the past. The dissection produced generally does not exceed 20 m in relief but the slopes are very steep (more than 35°). Most of the bedrock surface is covered by a thin veneer (less than 1.5 m thick) of silt and rock rubble derived through the action of mechanical and/or chemical weathering. The entire area has been inundated at some time by a standing body of water, resulting in a certain amount of sorting of the surface materials. Fine grained deposits may be expected to occur in depressions, scattered gravel beaches or lag concentrate may occur on the rises.	rCv CRs ₄ 4	these areas of carbonate and shale bedrock consist of steeply sloping (greater than 35°) scarp faces with maximum relief greater than 50 m. The scarps are in part covered by a veneer of rubbly colluvial debris moved to its present position predominantly through the action of gravity.
gAp ₂ 1-gAt ₁ 1	this area consists of gravelly alluvial deposits; 60-80% of the unit is a plain subject to annual flooding. The plain possesses slopes less than 5° and a total relief of 5-20 m. The remainder of the area consists of terrace gravels above the apparent limit of the spring flood. The terraces are very low, with slopes less than 5° and relief less than 5 m.				

Table 2: Soil and vegetation portion of the biophysical map legend.

Map Symbol	Ecoregion and Ecodistrict	Parent Material	Ground Ice and Ice Content	SOIL		Depth of Thaw (cm)	Vegetation
				Soil Association	Gen. Name and Drainage		
Ar1	L-2	Noncalcareous to weakly calcareous silty clay to clay marine deposit.	Massive ground ice in near surface permafrost (0.5 m or more thick). Ice lenses, segregated ice crystals and vein ice are also common. High ice content.	Arrowsmith River 1	Brunisolic Turbic Cryosol (I 7) Gleysolic Turbic Cryosol (P 3)	40-50 35-60	Ner, Et-Mo-L, Mo-L-Eo, Mo-Cx Et
Ar2		Noncalcareous to weakly calcareous silty clay to clay marine deposit.	Ice lenses, segregated ice crystals and vein ice. Medium ice content.	Arrowsmith River 2	Regosolic Static Cryosol (W)	70	Ner
Ke1		Noncalcareous marine sand.	Massive ice wedges and segregated ice crystals. High to low ice content.	Kellet River 1	Brunisolic Static Cryosol (W 8) Regosolic Static Cryosol (W 2)	35-70 80-90	L-Er, Cr-Mo-Dr, Mo-L Ner
Ke2		Less than 1.5 m of noncalcareous marine sand over marine clay.	Massive ice wedges and segregated ice crystals. High to low ice content.	Kellet River 2	Brunisolic Static Cryosol (W)	35-70	L-Er, Cr-Mo-Dr, Mo-L
Sp1		Weakly calcareous to noncalcareous recent sandy alluvium.	Ice lenses and segregated ice crystals. Low to medium ice content.	Stael Point 1	Regosolic Static Cryosol (P)	90	N
Sp2		Weakly calcareous to noncalcareous sandy alluvium.	Ice wedges, ice lenses and segregated ice crystals. Medium to high ice content.	Stael Point 2	Regosolic Static Cryosol (W,I 6) Brunisolic Static Cryosol (W,I 4)	60-80	L-Er, Ca-Mo-Dr, Mo-L
Pc		Coarse-grained igneous or metamorphic rock containing quartz as an essential component, along with feldspar and mafic minerals; mainly refers to granite and granite gneiss.	----	Precambrian Granitic Bedrock	----	--	N

NOTES:

Bedrock slope classes are assumed to be complex unless otherwise shown.

Stratigraphy: deposits less than 1.5 m thick are indicated as a veneer (v).

Drainage Distribution: The percentage of each drainage class is indicated by a decile number following the drainage symbol.

Soil Classification: See Proc. of the Ninth Meeting of the Canada Soil Survey Committee, Univ. of Sask., Saskatoon, May 16-18, 1973, p. 346-358.

Depth of Thaw: measured in August, 1974.

For abbreviations of plant species, see Appendix 1, Section C1.

the ecoregion symbol (see Figure 3). A description of this ecodistrict, L-2, in which the Pelly Bay West example lies, is as follows:

Ecodistrict L-2 - The western and central portion of this district (area between Pelly Bay, Arrowsmith River and L-1 district boundary) is a Precambrian upland with moderate relief. A discontinuous veneer of Pelly Bay till occurs mainly in valleys and depressions. The surface material of the eastern central part of this district, which lies in the Arrowsmith River area, is dominantly marine clay (Arrowsmith clay) while to the east, the terrain is dominated by low granitic hills with various amounts of Pelly Bay till and Arrowsmith clay. Kellet River sand commonly occurs in the southern part of this district. Massive ground ice, ice lenses and vein ice in the near surface permafrost are commonly associated with the Arrowsmith clay. Massive ice wedges associated with polygons are common in Kellet River sand and Stael Point sand. The ice wedges are especially well-developed where Kellet River sand overlays marine clay (mapped as Kellet River 2 soil association). Pelly Bay till is associated with only segregated ice crystals and small ice lenses.

Description of Ecoareas - The ecoareas are presented on the 1:125,000 biophysical maps (Tarnocai *et al.*, in preparation), and are classified and described according to their characteristic pattern of landform, soils and vegetation. The map symbols contain the soil association and vegetation cover class descriptors in the numerator and the genetic landform, relief and slope descriptors in the denominator (see Figure 4). The soil parent materials, ground ice, ice content, genetic soil name, depth of thaw and the dominant vegetation communities are found in the soil-vegetation portion of the map legend (see example in Table 2).

Most of the map units represent a single landform type, soil association and vegetation cover class on the biophysical map (e.g.

$\frac{Arl\ 5}{Mp}$). Composite map units, however, occur where these components are not separable at the 1:25,000 scale. In this case, the components are labeled separately and their percentage distribution is identified by a symbol (e.g. $\frac{Arl\ 5}{Mp} \frac{Pc\ 1}{gR\ 1}$).

ANTICIPATED USES

The interpretation of data presented in this

biophysical study was used for determining terrain sensitivity and trafficability ratings of the terrain and for estimating the granular resources of the area. These interpretations were carried out because of their importance for pipeline construction.

This information can also provide a basis for determining the capability of the terrain to support wildlife and also forestry and agriculture if a similar system is used in more southern areas.

COST ESTIMATE OF THE PROJECT

In total, 5.5 man-years (4 professional and 1.5 technical man-years) were spent on this project. This includes both the field work and the office and laboratory work portions. The estimated unit cost of the project was \$8±1/mi². This figure covers the field expenses, including the helicopter and fixed-wing flying, salaries, materials, equipment and shipping costs.

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of Canada, Open File (in preparation).

APPENDIX I

A. Description of Landforms - The genetic landform terms used in the Boothia biophysical maps, or modified terms based on subsequent work, are defined and briefly described below.

1. Origin

Morainal - Relating to accumulations of unsorted, unstratified glacial drift (till) deposited chiefly by the direct action of glacier ice in a variety of landforms that are primarily independent of control by the surface on which the drift lies.

Ice-Contact Outwash - Landforms consisting of stratified deposits formed in contact with melting glacier ice, such as an esker or kame.

Proglacial Outwash - Pertaining to the landforms and stratified deposits produced by meltwater flowing from wasting glacier ice.

Marine - Pertaining to materials deposited in marine environments. These may form a blanket of offshore silts and clays, or may occur as a series of marine nearshore features, largely composed of gravel and sand, such as spits, bars and beaches.

Deltaic - Refers to alluvial sediments deposited where rivers or streams enter (entered) standing bodies of water, forming broad, nearly horizontal tracts of land, large or small, which extend (extended) into the present (former) water body.

Alluvial - Sorted sediments of wide particle size range, transported and deposited by running water in postglacial time. Units are subjectively mapped as active or inactive. Active floodplains are those immediately adjacent to and below the assumed or apparent maximum annual flood level of the river or stream which deposited them. They commonly support only scant vegetation due to yearly flooding and deposition of fresh sediment. The surfaces of inactive floodplains are generally at an elevation of 1 to 3 m above the assumed or apparent maximum annual flood level.

Colluvial - A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity; may include soliflucted material on gentle or strong slopes.

Eolian - Pertains to deposits such as loess or dune sand whose constituents were transported, and deposited by wind.

Weathered Product - A general term referring to any significant occurrence of essentially *in situ* or cryoturbated unconsolidated or partially consolidated material derived from an underlying bedrock source through the action of mechanical and/or chemical weathering.

Bedrock - A general term for the rock, usually solid, that underlies unconsolidated surficial material, or is exposed.

2. Bedrock Type

Granitic - A term broadly applied to identify coarse-grained igneous or metamorphic rock containing quartz as an essential component, along with feldspar and mafic minerals; mainly refers to granite and granite gneiss; may include minor outcrops of other igneous, volcanic, or metamorphic rocks.

Carbonate - A term intended to identify rocks with consist primarily of carbonate minerals; mainly refers to limestones or dolomites; may include minor occurrences of conglomerate, breccia, sandstone, or shale.

Shale - A laminated sedimentary rock in which the constituent particles are predominantly of the clay or silt grades; may include minor outcrops of sandstone or carbonates.

Sandstone - A cemented or otherwise compacted detrital sediment composed predominantly of sand-sized quartz grains; may include minor outcrops of conglomerate, carbonates, or shale.

Conglomerate - A cemented clastic rock containing rounded fragments corresponding in their grade sizes to gravel or pebbles; may include minor outcrops of sandstone.

3. Morphology

Plain - An area of terrain, large or small, with little or no surface undulation; total relief and average slope indicated by appropriate numeric symbols.

Rolling - A gently to strongly defined succession of hills or broad undulations that impart a wave effect to the surface.

Hummocky - A term referring to the presence of moderately to strongly defined mounds, knolls, hillocks, or tors which may occur

in closely spaced groups mappable as a single terrain unit, or as individuals superimposed upon a rolling, ridged, or planar landscape.

Ridged - A term referring to the presence of gently to strongly defined linear hills or smaller surface undulations which may occur as large individuals or in closely spaced groups mappable as a single terrain unit, or as individuals or closely spaced groups of individuals superimposed upon a rolling or planar landscape.

Terraced - Refers to the presence of one or more, relatively level or gently inclined surfaces, bounded along one edge by a steep ascending slope and along the other by a steep descending slope. Terraces commonly occur along the margin and above the level of an ocean, lake or river, marking former water levels.

Kettled - An area characterized by numerous steep-sided, bowl- or basin-shaped depressions often containing a small lake or pond; primarily occurs only in ice-contact, or near-glacial, outwash deposits.

Fan - A gently to strongly sloping mass of alluvial or colluvial material forming a segment of a cone, commonly at a place where there is a noticeable change in gradient. Colluvial fans, deposited chiefly by mass wasting, are generally too small to map at a scale of 1:125,000. They are a common landform situated at the base of most scarps in bedrock-dominated terrain.

Scarped - An area containing one or more escarpments, cliffs or very steep slopes of some extent along the margin of a plateau, mesa, terrace, bench, or forming the sides of a valley.

4. Morphologic Modifier

Dissected - A term referring to a pattern of closely spaced gullies, ravines, valleys, or other linear depressions, and the remnant interfluvial ridges, formed by water erosion acting upon a gently undulating or planar topographic surface.

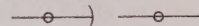
Washed - A general term referring to landforms which have been modified in some manner by wave action. The process has resulted in the sorting of surface materials, such that fine-grained sediment has been moved from high ground to adjacent depressions, or in the formation of scattered minor beaches.

Note: The term 'boulder covered', a morphologic modifier used in the Boothia

mapping project to indicate areas of felsenmeer, has been deleted from the updated version of the legend based on classification problems encountered on Somerset and Prince of Wales Islands. Classic felsenmeer is now being mapped as rsWv - rubble and sand weathered veneer. It is probable that much of the silty rubble overlying Paleozoic rocks of the high Arctic is also felsenmeer-like in its origin.

5. Special Symbols

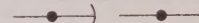
Drumlin, drumlinoid (ice direction indicated, not indicated)



Crag-and-tail (ice movement in direction of arrow)



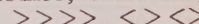
Fluting (ice direction indicated, not indicated)



Moraine ridge



Esker (direction of flow assumed, uncertain)



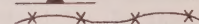
Pingo



Meltwater channel (large, small)



Abandoned beach ridge



Escarpment



Slump



Retrogressive thaw-flow slide



Frost-cracked terrain (including ice wedges)



B. Soil

1. Soil Classification of Cryosols

Order	Great Group	Subgroup
Cryosolic	Turbic Cryosol	Brunisolic Turbic Cryosol
		Regosolic Turbic Gleysolic Turbic Cryosol
		Brunisolic Static Cryosol
	Static Cryosol	Regosolic Static Gleysolic Static Cryosol

For a more detailed description of Cryosols see: Proc. of the Ninth Meeting of the Canada Soil Survey Committee, Univ. of Sask., Saskatoon, May 16-18, 1973, p. 346-358

2. Calcareous Classes - The classes are determined on the basis of the CaCO_3 equivalent. The classes are as follows:

- | | | | | |
|----|-----------------------------|--------|-----------------|------------|
| a) | Weakly
calcareous | 2-5% | CaCO_3 | equivalent |
| b) | Moderately
calcareous | 6-15% | " | " |
| c) | Strongly
calcareous | 16-25% | " | " |
| d) | Very strongly
calcareous | 26-40% | " | " |

Eo - *Eriophorum angustifolium*
 Et - *Eriophorum tussock* (*Eriophorum vaginatum*)
 L - Lichens
 Mo - Mosses
 N - Unvegetated (*Nudum*)
 Sa - *Saxifraga oppositifolia*
 Sx - *Salix arctica*

(Modifier abbreviations)

cb - Cryoturbated
 er - Eroded

3. Soil Drainage Classes - The three soil drainage classes used are described below:

Well drained - Water is removed from the soil readily but not rapidly. Well drained soils are commonly coarse to intermediate in texture, although soils of other textural classes may also be well drained. Well drained soils, especially coarse textured materials, have the deepest active layer.

Imperfectly drained - Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile, a high water table, additions through seepage, or a combination of these conditions.

Poorly drained - Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface during a considerable part of the year. Poorly drained conditions are due to a high water table, to a very shallow active layer, to seepage or to some combination of these conditions.

In Table 2 drainage classes are abbreviated as follows: W - well drained; I - imperfectly drained; and P - poorly drained.

C. Vegetation

Vegetation communities are named according to the dominant species and listed (see Table 2) in order of increasing moisture condition of the site. The species abbreviations used in Table 2 are shown below.

Ca - *Carex rupestris*, *Carex scirpoidea*
 Cs - *Cassiope tetragona*
 Cr - *Carex misandra*, *Carex saxatilis*
 Cx - *Carex stans*
 Dr - *Dryas integrifolia*
 Er - Ericaceae (*Ledum decumbens*, *Vaccinium uliginosum*, *V. Vitis-idaea* var. *minus*)

in closely spaced groups mappable as a single terrain unit, or as individuals superimposed upon a rolling, ridged, or planar landscape.

Ridged - A term referring to the presence of gently to strongly defined linear hills or smaller surface undulations which may occur as large individuals or in closely spaced groups mappable as a single terrain unit, or as individuals or closely spaced groups of individuals superimposed upon a rolling or planar landscape.

Terraced - Refers to the presence of one or more, relatively level or gently inclined surfaces, bounded along one edge by a steep ascending slope and along the other by a steep descending slope. Terraces commonly occur along the margin and above the level of an ocean, lake or river, marking former water levels.

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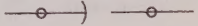
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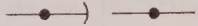
Note: The term 'boulder covered', a morphologic modifier used in the Boothia

mapping project to indicate areas of felsenmeer, has been deleted from the updated version of the legend based on classification problems encountered on Somerset and Prince of Wales Islands. Classic felsenmeer is now being mapped as rsWv - rubble and sand weathered veneer. It is probable that much of the silty rubble overlying Paleozoic rocks of the high Arctic is also felsenmeer-like in its origin.

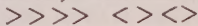
5. Special Symbols

Drumlin, drumlinoid (ice direction indicated, not indicated) 

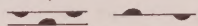
Crag-and-tail (ice movement in direction of arrow) 

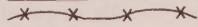
Fluting (ice direction indicated, not indicated) 

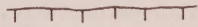
Moraine ridge 

Esker (direction of flow assumed, uncertain) 
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Pingo

Meltwater channel (large, small) 

Abandoned beach ridge 

Escarpment 

Slump 

Retrogressive thaw-flow slide 

Frost-cracked terrain (including ice wedges) 

B. Soil

1. Soil Classification of Cryosols

Order	Great Group	Subgroup
Cryosolic	Turbic	Brunisolic Turbic
	Cryosol	Cryosol
		Regosolic Turbic
		Gleysolic Turbic
		Cryosol
	Static	Brunisolic Static
	Cryosol	Cryosol
		Regosolic Static
		Gleysolic Static
		Cryosol

For a more detailed description of Cryosols see: Proc. of the Ninth Meeting of the Canada Soil Survey Committee, Univ. of Sask., Saskatoon, May 16-18, 1973, p. 346-358

AN EVALUATION OF REMOTE SENSING TECHNIQUES FOR ECOLOGICAL
(BIOPHYSICAL) LAND CLASSIFICATION IN NORTHERN CANADA

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ABSTRACT

The use of LANDSAT satellite and airborne remote sensing imagery are evaluated in a sub-arctic and northern boreal environment near Churchill, Manitoba. Accuracy and cost-effectiveness of a number of interpretation methods are compared, including visual and automated (supervised and unsupervised) techniques of LANDSAT data and air photo interpretation. Classification results of the different techniques are compared by using the overlay capabilities of the Canada Geographic Information Computer System. Conventional interpretation of aerial photographs enabled classification of about 43 different land types, and proved the best and most practical method for comprehensive biophysical mapping. Satellite-based methods allowed the mapping of about 10 groups of land types, often so broad that their practical value for resource management is limited. At present, visual satellite interpretative methods are more cost-effective than automated approaches for ecological land classification in most parts of Canada.

INTRODUCTION

Environmentally sound resource management requires basic biological-physiographical and socioeconomic data that allow an integrated or multidisciplinary approach. In the southern developed part of Canada, the Canada Land Inventory Program has provided a multidisciplinary land capability mapping. One-third of our land area is covered with this nationally consistent information base. For about 3.5 million km² of land in the north, there is a serious lack of such base line data (Romaine, 1974).

The National Committee on Forest Land, working under the auspices of the Canada Land

RESUME

L'emploi de satellites de LANDSAT et d'images obtenues par télédétection aérienne est évalué dans un milieu subarctique et boréal près de Churchill, au Manitoba. L'exactitude et le rapport coût-efficacité d'un certain nombre de méthodes d'interprétation, y compris les techniques visuelles et automatisées (avec ou sans surveillance) d'interprétation des données LANDSAT et de photo-interprétation, sont comparées. Les résultats de la classification des diverses techniques sont comparés par l'exploitation des possibilités de recouvrement de l'ordinateur du système d'information géographique du Canada. L'interprétation classique des photographies aériennes a permis de classer environ 43 types de terrains, et s'est avérée la meilleure et la plus pratique des méthodes de cartographie biophysique. Les méthodes utilisant les satellites ont permis de dresser des cartes d'environ 10 groupes de types de terrains, souvent si généraux que leur applicabilité à des fins de gestion des ressources est limitée. A l'heure actuelle, les méthodes visuelles d'interprétation des images prises par satellite sont plus efficaces, relativement au coût, que les méthodes automatisées en ce qui concerne la classification écologique des terres dans la plupart des régions du Canada.

Inventory Program, recognized this gap in environmental data and through its sub-committee, started the development of a classification system to provide this biological-physiographical data base for 'wildlands'. The biophysical land classification system evolved. The further development of this system is now supported by the Canada Committee on Ecological (Bio-physical) Land Classification.

The aim of the classification system is to differentiate and classify, at a small scale, ecologically significant segments of the land surface (Lacate *et al.*, 1969). It was recognized that this system should be ecolog-

ically based, and that mapping and the description of land surfaces, and assessments related to forestry, wildlife, recreation, agriculture, etc., could be made rapidly and with little additional effort. The system has four levels in its classification hierarchy. *Land region*, the first level, is defined as an area of land characterized by a distinctive regional climate as expressed by vegetation. The second level, *Land district*, is basically a sub-division of the land region based primarily on the separation of major physiographic and/or geologic patterns that characterize the region as a whole. *Land system*, the third level, is defined as land areas throughout which there is a similar recurring pattern of landforms, soils and vegetation. The fourth level, *Land type*, could also be called a land ecosystem. It has a fairly homogeneous combination of soil and chronosequence of vegetation. Mapping scales suggested are as follows:

Land Region	1:1,000,000 - 1:3,000,000
Land District	1:500,000 - 1:1,000,000
Land System	1:125,000 - 1:25,000
Land Type	1:10,000 - 1:20,000

The objective of this paper is to report on the usefulness of airborne and satellite remote sensing for biological-physiographical data gathering in northern areas. As low cost and rapidity are considered critical, most attention is given to the evaluation of LANDSAT data. Different interpretation methods are tested in an area near Churchill, Manitoba, where boreal and arctic elements are present.

Air photo interpretation has played a significant role in the development of environmental survey systems related to vegetation, surficial geology, soils, forestry and agriculture including biophysical land classification. In the early 1950's, Hills recognized the value of aerial photographs for his forest site (physiographic site) classification. He stressed landform and surface geology as the integrating framework for vegetation, soils, local climate and 'site'. The value of landforms in delineating and describing site conditions was supported by Gimbarzevsky (1966) and Lacate (1966). Stereoscopic viewing of aerial photographs provides a three-dimensional image of terrain features. Relief and slope are important indicators of ecosystem parameters such as drainage, parent material, soil formation and vegetation succession (Thie, 1972). Good perception of depth in a stereo model and quick analysis of shapes and textures enable the human interpreter to readily separate significantly different units. Following field descrip-

tions of selected sample areas, results can be extrapolated to non-sampled similar areas by means of photo-interpretation. With this approach, the total number of field investigations is considerably less than in conventional surveys. The value of each field observation is much greater; therefore, both its choice location, and its description and classification are more critical (Vink, 1964).

As a result of the development of new remote sensors, the interpretation methodology is changing rapidly. Much of the 'imagery' generated by airborne and satellite sensors is now stored in an analogue or digital fashion on magnetic tape. Transforming these into visible images for human interpretation usually significantly reduces spectral information and spatial resolution. Computer interpretation of images should not entail loss of information.

The introduction of the airborne program of the Canada Centre for Remote Sensing (CCRS) and the launch of the Earth Resources Technology Satellites (ERTS, presently called LANDSAT) pushed the research in application of remote sensing in Canada rapidly ahead. Much of the work, at one time carried out in the U.S., now came within reach of Canadian researchers. These Canadian experimenters in remote sensing-assisted soil mapping, terrain studies and biophysical inventories (Beke, 1972; Boydell, 1974; Desloges, personal communication; Gimbarzevsky, 1974; Howarth, 1976; Mills, 1972; Oswald, 1975; Tarnocai, 1972; Tarnocai and Thie, 1974; Thie, 1972, 1976; and Thie *et al.*, 1974) used visual and automated methods of analysis.

STUDY AREA

To evaluate airborne and satellite remote sensing for northern land classification, an area was chosen in that part of northern Manitoba where arctic and boreal elements meet (Figure 1). Two main physiographic regions also meet in this area - the Canadian Shield and the Hudson Bay Lowland. In this area, the disturbance of natural vegetation by man and fires is insignificant; surface vegetation can be considered as a good indicator of subsurface conditions, and therefore also of the geographic distribution of land types or ecosystems.

Using LANDSAT imagery, the area was subdivided into two land regions and five land districts (Figure 1). Although the boundary of the land regions is actually based on a physiographic divide, the difference in the first place is climatic. This climatic difference is expressed in the distribution of

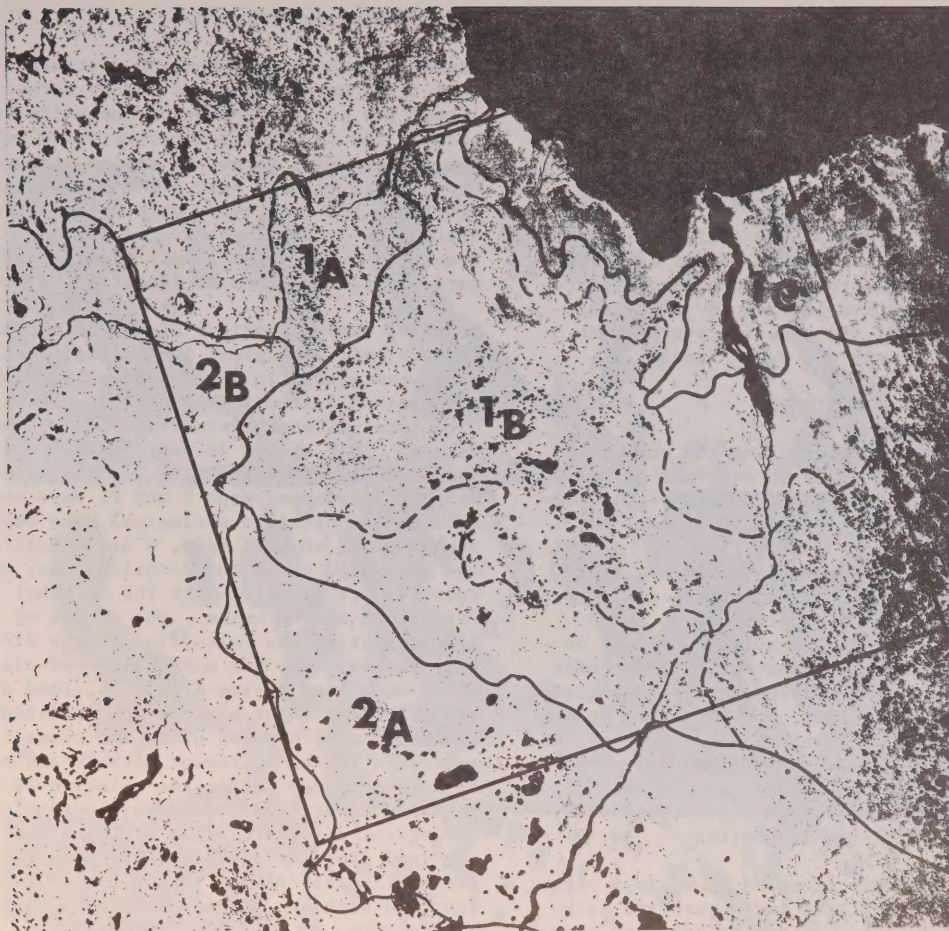


Figure 1: Land districts in the Churchill map-sheet (54L). The square area outlined in heavy lines represents the 54L sheet. Background is an image taken 14 Aug. 1973 (1387-17021-band 7). Continuous lines delineate the land districts; broken, the 'transition' zones.

vegetation and permafrost occurrence.

LAND REGION (1) has continuous and widespread discontinuous permafrost (Brown, 1967), a prevalent forest-tundra type of vegetation (Ritchie, 1962), and an arctic climate.

The *Seal River District (1A)* is characterized by a relatively thin layer of stony till over bedrock, partly overlain by extensive peat deposits. Water-modified glaciofluvial deposits, till ridges, and beaches occur throughout the area. Till covers about 35% of the area. In wet to moist areas, strong frost heaving of stones and rocks in the till has resulted in rock and stone fields. In the peatlands, peat polygons occur, as well as sedge wetlands.

The *Lofthouse-Lovett Lake District (1B)* consists of 99% organic deposits over marine sediments and till. Glaciofluvial deposits provide the only areas of dry land. In the peatlands, peat polygons occur more frequently (40%), associated with patterned sedge fens (30%).

The *Coastal District (1C)* is the most complex district in the study. This narrow strip along the coastline consists of extensive marine flats, alluvial deposits, numerous beach ridges, and a thin layer of relatively recent organic deposits. Occasional bedrock and glaciofluvial deposits are found. Wetland types are sedge fens, peat plateaus, palsas and salt marshes.

LAND REGION (2) is marked by widespread discontinuous permafrost, open coniferous forest

and a north boreal and arctic climatic.

In the *Mack Lake District* (2A), more than 95% of the surface material is peat. Peat plateaus form the dominant landforms reflecting the gently undulating topography controlled by a thick overburden of till over Precambrian bedrock.

In the *Knife River District* (2B), till is the dominant surface material. It has a vegetation cover to open to semi-open black spruce. Local fires may have introduced jack pine. Only about 20% of the area is covered with peat (peat plateaus and sedge fens).

METHODS

Fieldwork, carried out during the summers of 1973 and 1974, entailed an aircraft survey and the sampling of landform-soil-vegetation-permafrost complex in about 100 locations.

Remote sensing photography, including high altitude coverage for the complete study area and low altitude and radar coverage for selected parts of the area, was obtained on different dates during the spring and summer of 1973. The standard sensor package included colour infrared, colour, and black and white photography combined with various filters, and thermal infrared scanning (Figure 2). Moreover, various LANDSAT images in the form of prints, transparencies and digital tapes were used in the satellite evaluation

To compare the effectiveness of various visual and automated satellite interpretative techniques, three different ecological land classification maps were prepared:

MAP I - based on the visual interpretation of 1:1,000,000 multirate LANDSAT imagery.

MAP II - based on the visual interpretation of a LANDSAT colour composite, digitally enlarged to 1:250,000 scale.

MAP III - based on a supervised automated interpretation using the Multispectral Analyser Display (MAD) of the CCRS.

In addition, parts of the study area were mapped using unsupervised automated classification techniques and supervised and unsupervised multirate (summer-winter combination) interpretation techniques as implemented on CCRS Image 100 and MAD systems.

To measure the success of each map, it was compared with a detailed ecological base map. This map is based on field sampling and visual interpretation of 1:100,000 scale black and

white aerial photographs.

Based on field work, about 50 representative land types were recognized. They formed the legend for classification of map units (or pixels) for any of the interpretative methods. For convenience, these are called *classes*. Grouping of classes into *class groups* was done when the land types were not spectrally separable, or were cartographically or resolution-wise unmappable. A simple alphanumeric system was used to identify the classes.

To allow easy comparison of the interpretative results, all ecological land classification maps were stored in the Canadian Geographic Information System (CGIS) of the Lands Directorate, Department of the Environment, Ottawa. This system is designed to read, store, analyse, manipulate, and overlay maps. Using this system, Maps I and II were overlaid on the detailed ecological base map. For each mapping on both maps, a new classification was generated using the detailed base, and the results were compared with the original classification of the units. The amount of misclassification was calculated as the difference from the base map for each class and class group on a land system (Table 1), land district and total map sheet basis. The individual performance of mapping units and classification generated by the different methods are measured on a land system basis; the relation of classification performance and physiographic and ecological characteristics are obtained through the land district analysis. Because of geometric distortions, Map III was visually compared with Map IV and detailed aerial photographs.

RESULTS

The maps generated by the visual interpretation methods are partly displayed in Figure 3. The results of the supervised automated classification are displayed in Figure 5. To compare the various maps, at least four aspects have to be considered.

1. The number and size (detail) of the units on the map.
2. The number of land types (ecosystems) that are used in the legend.
3. The classification accuracy of the mapping units.
4. The accuracy or significance of the land system (mapping unit) boundaries.

On the ecological base map, 700 land systems were mapped, each covering about 1800 ha. Map II, resulting from the visual interpretation of 1:250,000 satellite imagery, has 167 land systems for three areas covering about 25% of

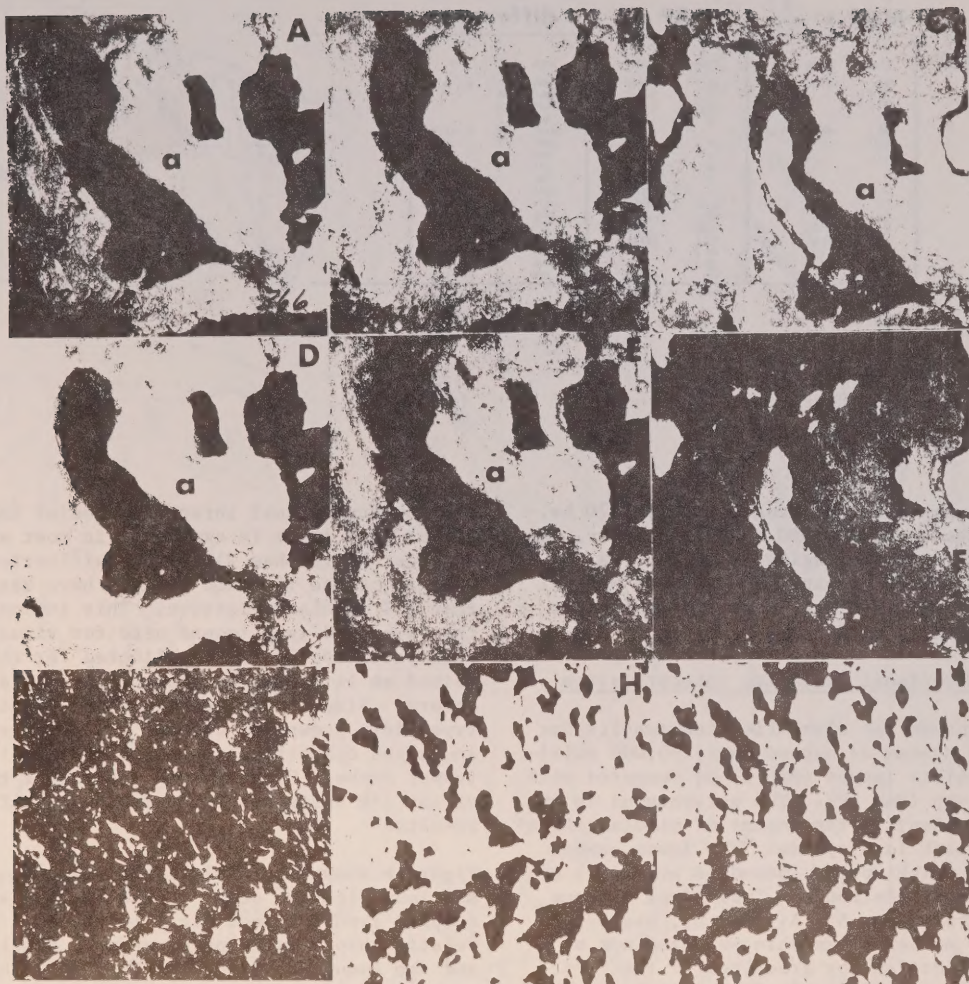


Figure 2: Airborne multiband coverage of the Long Lake area. Two flights took place at an altitude of 3,050 m ASL. A, B, D, E and H were taken 22 July 1973; C, F, G (at 10,700 m ASL) and I were taken 1 June 1973. A (CP28741R-366) was taken with a 2443 film with CC20M filter; B (CP28721R-366) with a CC20B filter; D (BN2873-366) with a 2405 film combined with a W12 filter ('Red Band') and (CP2875-366) a colour photo. H and I are thermal scanning images taking simultaneously with the 70 mm Vinten camera imagery. G (RSPA-306651R) is part of a 9" by 9" small scale colour infrared photo.

Table 1: Computer-Generated Overlay Results. In this example of computer-generated overlay results, Maps I and IV, the land system (no. 543300124) is described by two columns with classes. The left column shows the method to be tested (Map I); the right column shows the 'true' classification based on (Map IV).

MAP I				MAP IV			difference			
LANDSYSTEM 543300003	CLASS	AREA	Z	CLASS	AREA	Z	AREA	Z	A	Z
	A3	31593	60	A1	3888	7	3888	7	A	3.0
				A3	16629	32	-14964	-28		
				A31	12670	24	12670	24		
				B1	600	1	600	1		
	B2	10531	20				-10531	-20	B	-18.9
				C2	4007	8	4007	8	C	7.6
				D1	104	0	104	0	D	6.3
				D2	174	0	174	0		
				D3	791	2	791	2		
				D5	2225	4	2225	4		
	E1	10531	20	E1	7354	14	-3176	-6	E	-6.0
				G1	1501	3	1501	3	G	6.0
				C12	523	1	523	1		
				G2	1133	2	1133	2		
				O2	214	0	214	0	O	1.6
				O3	644	1	644	1		
				P1	196	0	196	0	P	0.4
	TOTAL			52655 100			53.5 24.9			

the total map area; coverage size is 2370 ha. Map I, based on 1:100,000 LANDSAT imagery, has 149 land systems averaging about 9100 ha. Thus, the levels of mapping detail of Maps II and IV are similar; Map I, however, displays significantly larger units.

1:1,000,000 Visual Satellite Interpretation

Figure 4 shows the classification results for each land system as mapped on 1:100,000 multi-date satellite images (Map I) as compared with the base map (Map IV). The percentages in the map units identify the amount of misclassification for each land system. The lower number gives the weighted sum (based on averages) of the misclassification for individual classes or land types (A₁, A₂, A₃, B₁, B₂, etc.). The upper number gives this weighted sum of misclassification for groupings of the individual classes (A, B, C, D, etc.) for that land system. Misclassification for each class group of classes is based on the areas of omission per class or per class group by land system as a percentage of land area. For example:

arising from visual interpretation of individual land types is excessive in most areas. The best system has 21% misclassification. Only 11 of the 149 land systems have better than 35% misclassification. This indicates that the land type legend used for visual interpretation is too complicated for this method as it causes excessive classification errors. Simplifying the legend by joining land types into groups of classes (A, B, C, etc.) increases classification accuracy significantly (upper number, Figure 4) to the extent that 58 of the 149 units have acceptable classification results.

Figure 4 shows that relatively large amounts of misclassification occur in the smaller and more complex land systems. It illustrates a relationship between physiographic complexity and the amount of misclassification. The greatest amount of misclassification is found in areas where mineral deposits occur. While peat-dominated areas, such as the peat plateaus in the SW part of the map area, have relatively good classification results (5%-20% misclassification), till-dominated areas nearby in land region 2 are misclassified by as much as 90%. However, mineral soils in land region 1 are significantly better-classified (about 30% misclassification). This possibly arises from the relative lack of vegetation and the lack of vegetation disturbance in the area, which results in less confusion during interpretation. Figure 4 also shows that higher amounts of misclassification are associated with the coastal

As shown by the lower numbers on Map V (Figure 4), the amount of misclassification

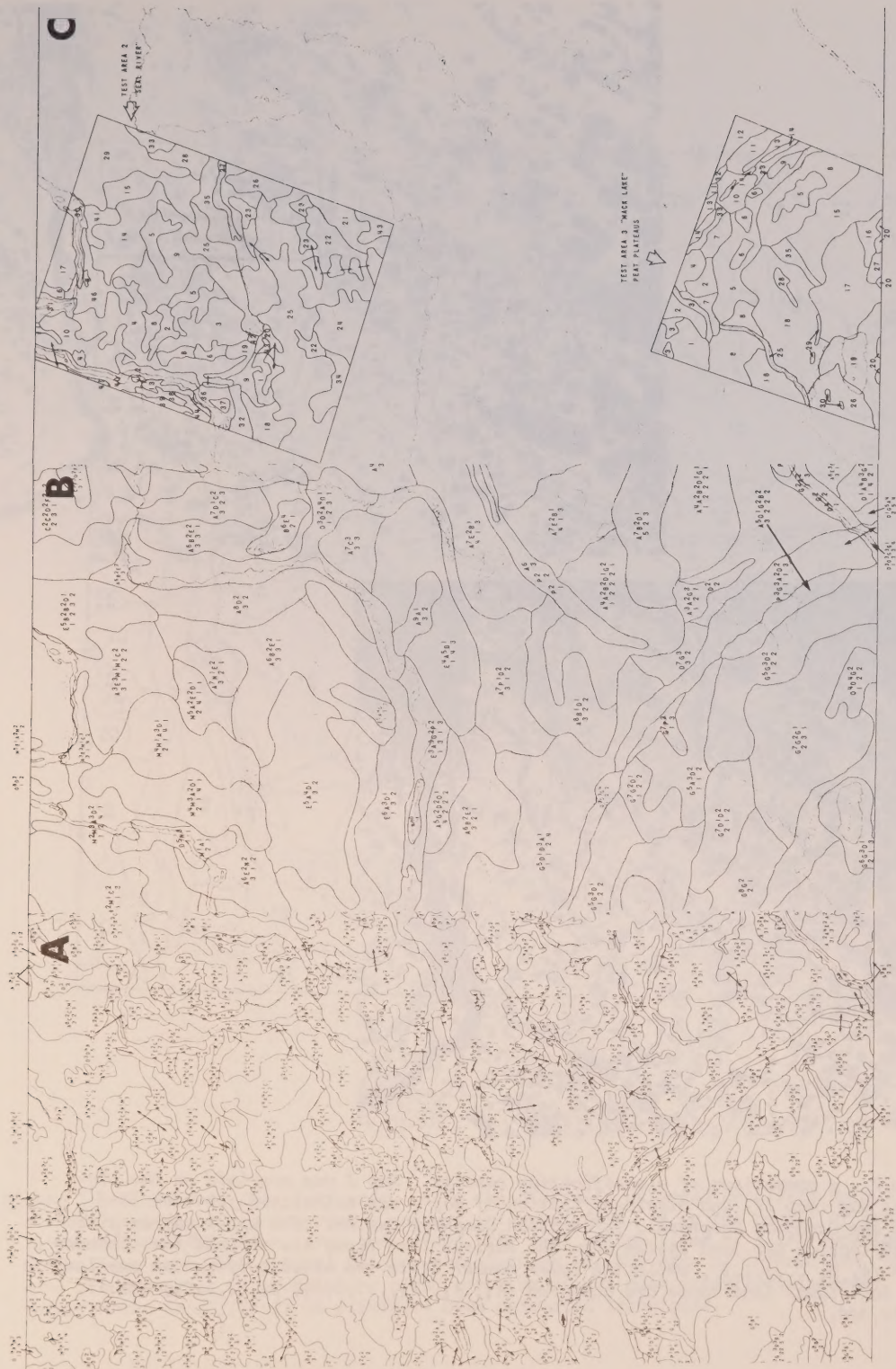


Figure 3: Visual interpretative methods. A shows part of the detailed ecological base map; B is the same area interpreted from 1:1,000,000 LANDSAT imagery; and C shows parts interpreted from 1:250,000 scale enlarged LANDSAT images.

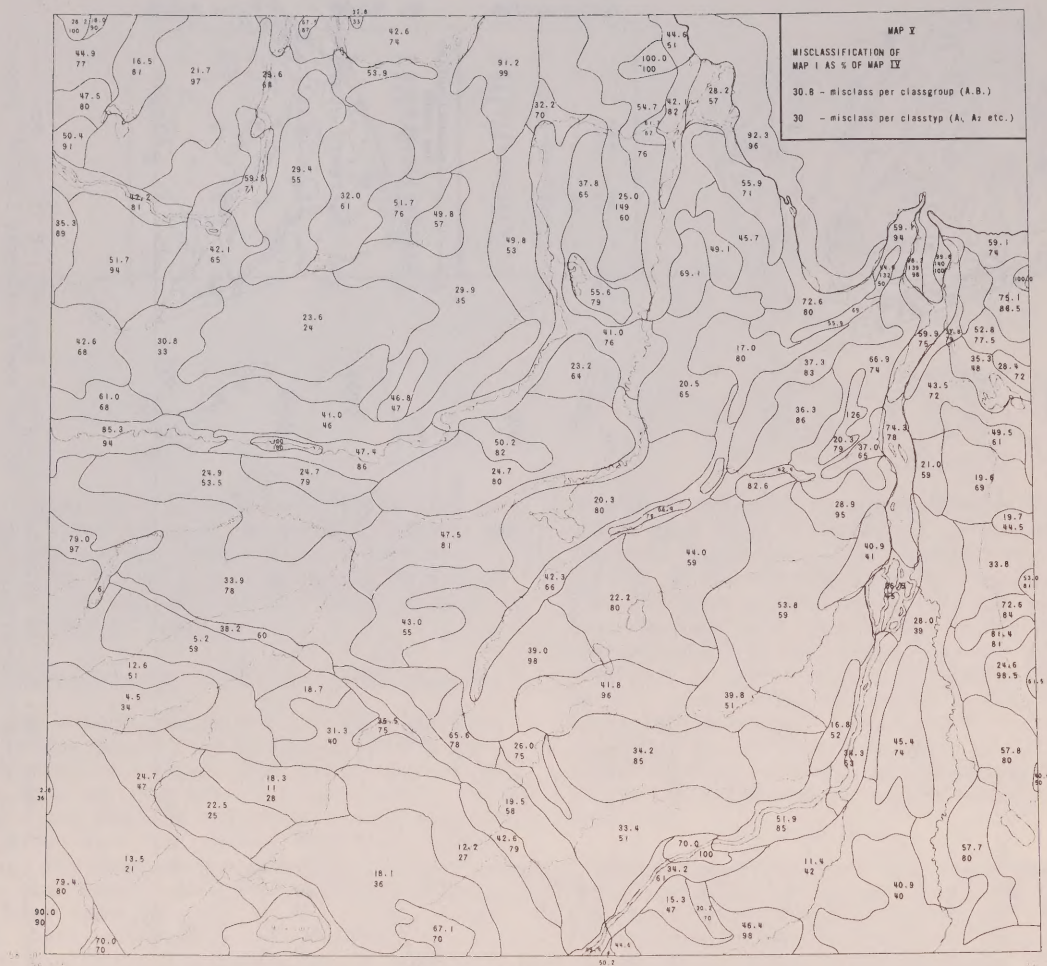


Figure 4: Map V - a comparison of classification results. Map I was overlaid on the bio-physical base map (Map IV) and misclassification of Map I was calculated for each land system using the Canadian Geographic Information Computer System. The upper number gives the misclassification per land system when the various land types are grouped into broader class groups (A, B, C.....Z), while the lower number lists the misclassification per land system when individual land types are compared (A₁, A₂, A₃,.....B₁, B₂,.....C₁, etc.). Scale - 1:750,000.

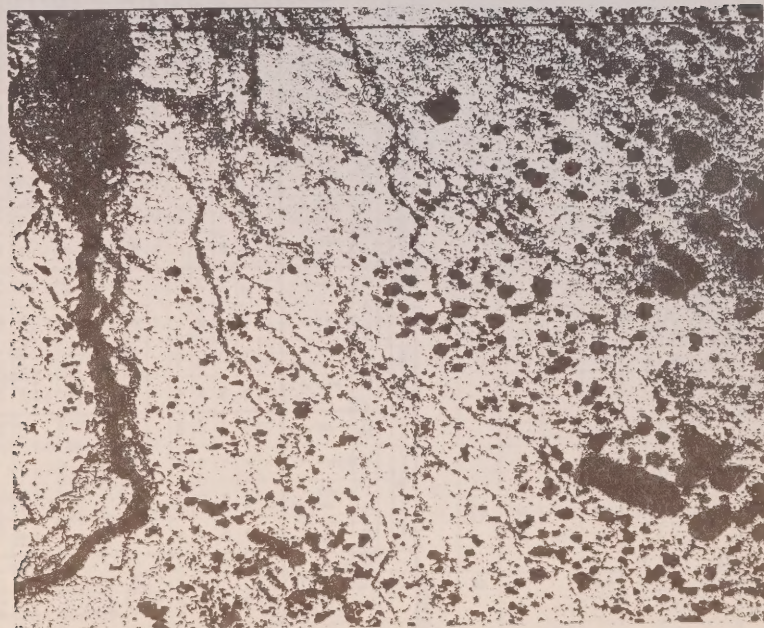
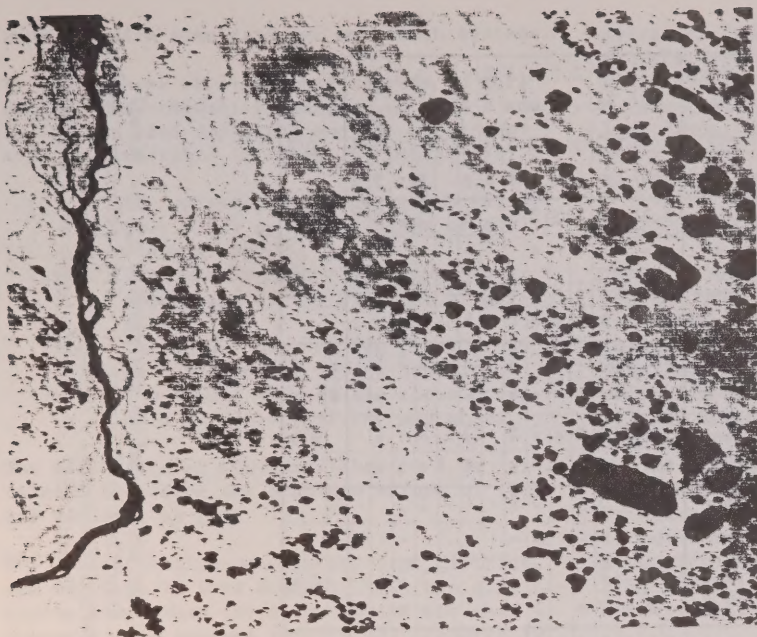


Figure 5: The Lovett Lake test area. A is the digitally enlarged satellite colour composite, with delineation of land system by visual interpretation. B is the result of supervised automated classification. For comparison, the land system lines of A are superimposed on B. While there is a good general relationship between the two sets of information, there are some discrepancies in areas where cloud cover or slight haze interferes (arrows). Such interference is difficult to eliminate with automated techniques.

TOTAL MAPSHEET										7th DISTRICTS										LOFTHOUSE - LOVELLY LAKES DISTRICT										COASTAL DISTRICTS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
BLACK LAKE DISTRICT (2A)					WHITE RIVERS DISTRICT (2B)					SEAL RIVER DISTRICT					TRANSITION DISTRICTS 2 and 3					TRANSITION 1C and 24C					DISTRICT 1C					TRANSITION (2) and 1C					DISTRICT 1C					TRANSITION (2) and 1C																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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Table 2: Summary of misclassification per land district and for the total map area based on the results of the visual interpretation of 1:1,000,000 LANDSAT imagery. The class groups can be described as follows: A - Peat polygonal areas; B - Carex fens; C - Larix fens; D - Picea-dominated peatlands; E - Patterned fen areas; F - Marshes and swamps; G - Peat plateaus; H - Palsas; I - Mud flats; M - Stone fields; N and O - Glacial till; P - Sandy beach and glaciofluvial deposits; R - Bedrock outcrop; Z - Water.

zone and with some drainage and beach systems.

To study these physiographic aspects in more detail, the computer comparison of Maps I and IV for the land districts and the total map area is summarized in Table 2. Listed are:

- (i) The omission per class group (A, B, C,.....Z) as a percentage of the class group.
- (ii) The omission per class group as a percentage of the district or map sheet.
- (iii) The actual area of the class group as a percentage of the district.
- (iv) The actual area of the class group as a percentage of the map sheet.

The percentage of *misclassification A* is calculated by adding the absolute values of (ii) and dividing by two.

The classification results per land district and map area in this summary table are significantly lower than those identified for the separate land systems (Figure 3). Apparently, errors are cancelled out in the summation process. For example, in the Mack Lake District, misclassification A is 10.1% while Figure 3 shows that most land systems in this district have significantly higher amounts. To obtain a more accurate indicator, the classification performance for each land system was weighted according to acreage and summarized; it is called *misclassification B*.

Table 1 shows that the Coastal and Knife Rivers districts have the poorest classification results, followed by the transition zones of districts (1B-1A) and (1B-1C). All three areas are physiographically complex. The relatively simple 'Mack Lake' district has the best classification performance: misclassification A is 10.1% and misclassification B is 14.7%. About 74% of this district is composed of peat plateaus. These are only 3.4% overclassified, mainly at the cost of sedge-dominated areas (class B) which as a result of generalization are consistently underclassified.

The Lofthouse-Lovett Lakes district and the Seal River district perform equally well on a land system basis, in spite of the fact that the Seal River area contains a significant proportion of mineral deposits (39% M and O). In both districts, peat polygons represent a large part of the unit (between 30% and 50%) and are consistently well-classified. In the Seal River district, the classification of

patterned fens and stone fields is reasonably satisfactory (34% omission). In the latter, it is thought that the lack of vegetation on M (stone fields) has helped to identify the land types. Considerable confusion with O (till areas) is expected, as classes M₂ and M₃ include parts of O.

1:250,000 Scale LANDSAT Visual Interpretation

Table 3, showing the classification results for the Mack Lake, Seal River and Lovett Lake test areas, is similar to Table 2. From the results of misclassifications A and B, the detailed interpretation clearly does not compare well with the results of Map I based on 1:1,000,000 LANDSAT interpretation. The Map I results are clearly equal to or better than Map II results. Although delineation of a land system at the detailed scale is more accurate, it is not matched by a similar increase in classification accuracy. The interpretation time involved for Map II is only slightly less than that required for interpretation of aerial photographs.

CLASS	MACK LAKE				SEAL RIVER				LOVETT LAKE			
	omission as % of class	omission as % of area	total of class as % of area		omission as % of class	omission as % of area	total of class as % of area		omission as % of class	omission as % of area	total of class as % of area	
A	-408	-16.0	3.9	25	9.5	38.0	16	6.6	41.8			
B	-29	-1.7	5.8	-54	-12.5	23.1	-5	-1.9	41.1			
C	-371	-5.4	1.4	19	2.0	10.7	-157	-4.4	2.8			
D	54	6.2	11.5	7	0.2	3.4	9	0.1	8.5			
E	-	-	-	-	-	-	-	-	-			
F	-	-	-	-292	0.2	0.1	31	0.3	0.9			
G	+20	14.8	73	-8756	-2.8	0.0	-14	-0.5	3.8			
H	-	-	-	-	-	-	-	-	-			
I	-	-	-	-	-	-	-	-	-0.2	-		
M	-	-	-	-11.0	-1.6	15.0	-	-	-			
N	-	-	-	-	-	-	-	-	-			
O	70	1.1	1.5	49	4.1	3.3	100	0.5	0.5			
P	3.5	1.0	2.9	100	0.7	0.7	100	0.0	0.0			
R	-	-	-	100	0.5	0.5	-	-	-			
Z	-	-	-	-	-	-	100	0.3	0.3			
Total	na		100	na		99.8	na		100.0			
% misclass A		23.1			16.9			7.1				
% misclass B		38.2			33.4			26.2				

Table 3: Summary of classification results for the three tests areas based on the results of 1:250,000 scale visual satellite interpretation.

AUTOMATED SATELLITE CLASSIFICATION

There are two different approaches to automated classification: supervised and unsupervised. Each was applied to single- as well as multiday satellite imagery. LANDSAT I tapes RS0198 and RS035 were used; moreover, summer and winter data are combined using band 7 of RS2863 (30 October 1972) and bands 5, 6 and 7 of RS2940 (27 July 1972).

Supervised Automated Classification

In supervised classification, the interpreter selects the objects to classify and identifies training areas for the computer. Training areas were selected across the whole image by available ground control and photo-interpretation. This procedure allows the selection of relatively large, pure and representative sites for the respective land types. Classification was carried out using the CCRS computer, MAD (Multispectral Analyser Display) and the MICA interpretation package, developed by scientists at the CCRS. For the classification, the Maximum Likelihood Decision Rule was used in all evaluations, as implemented on the CCRS computer. After about 15 iterations of training, displaying, classifying and an analyzing training statistics, a final training set evolved. This set, including water, represents 10 different class groups.

Table 4 shows the divergence and confusion matrix for the class statistics, and the final set. An increase in the number of classes was found to increase confusion and to give less satisfactory results. Initially, in the training process, an attempt to show land types (A₁, B₁, B₂, C₃, etc.) was tested, but confusion between spectral signatures of land types made it impossible at this level and quite broad class groups were used.

Using the final training set, the complete satellite image was classified (Figure 6). This result was subjectively evaluated on a land district basis by comparison with the ecological base map, detailed aerial photographs, and ground sampling. Figure 6 demonstrates the differences and relationships between the unclassified images, automated classification and visual interpretation.

Table 5 shows the results of this evaluation. The ratings only identify the classification accuracy of the different classes in the training set. Whether the particular class itself is satisfactory from an ecological viewpoint is not considered. Table 5 shows that the overall performance of the classifier is satisfactory. Best results (70%) are achieved in the Mack Lake, Knife Rivers and

DIVERGENCE MATRIX									
	CLASS								
	1	2	3	4	5	6	7	8	9
1	0.00								
2	15.78	0.00							
3	29.71	80.78	0.00						
4	69.29	24.64	105.96	0.00					
5	255.62	343.49	305.87	776.03	0.00				
6	51.28	77.46	30.56	130.40	612.99	0.00			
7	64.68	90.33	45.13	160.84	809.39	18.54	0.00		
8	54.83	130.89	32.09	267.86	531.33	8.68	37.20	0.00	
9	6.56	42.06	17.60	122.87	311.42	32.30	33.39	38.17	0.00

CONFUSION MATRIX									
Chosen Class	True Class								
	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	1	0
1	89	3	0	0	0	0	0	0	10
2	1	96	0	0	0	0	0	0	0
3	0	0	94	0	0	0	0	5	2
4	0	1	0	100	0	0	0	0	0
5	0	0	0	0	100	0	0	0	0
6	0	0	0	0	0	89	5	5	0
7	0	0	0	0	0	3	95	2	1
8	0	0	1	0	0	8	0	86	0
9	10	0	5	0	0	0	0	1	87

MEAN SPECTRAL INTENSITIES					
Class	Band	4	5	6	7
1 - sedge-ba/th		15.4	13.0	19.6	11.7
2 - open black spruce		14.8	11.1	21.9	12.9
3 - stonefields		18.3	16.2	21.1	11.1
4 - willow - alder-birch		14.9	10.5	27.5	18.3
5 - water		13.2	9.2	7.1	0.9
6 - peat plateaus		19.1	18.4	27.9	17.7
7 - peat polygons		17.5	17.4	25.7	17.3
8 - lichen/sand-till		20.5	19.5	27.7	16.8
9 - patterned fens		16.7	14.7	21.2	12.6

Table 4: Divergence and Confusion matrix and means statistics for the 'final' training set.

Seal River districts, possibly because these districts have seven or fewer classes. The Lofthouse-Lake district and its transition zones perform uniform with about 65% classification accuracy. The Coastal Zone has the poorest showing: none of the classes except 'water' and 'willow/alder/birch' perform well.

Although the classification results can be described as satisfactory for the total map area, they do not indicate that the automated classification can generate useful results. The nine-class final legend is too broad and too simple to be of much value. As a vegetation classification, the results could be considered successful; however, as a biophysical classification, the method performs poorly. As there is a relation between classification results of land districts and distribution of classes, automated classification may be improved by classifying on a land district basis. This procedure implies that training takes place within a district and is repeated for each district, and that legends



Figure 6: Map III - A supervised automated classification of the Churchill area. Map-sheet 54L is identified by thick line. Colour themes were generated through the use of the CCRS Multispectral Analyser Display (MAD).

dark blue	- water	brown	- peat plateaus
light blue	- sedge-bs/tl	yellow	- peat polygons
green	- open spruce	pink	- lichen/sand-till
red	- stone fields	grey	- patterned fens
orange	- willow-alder	black	- unclassified.

Table 5: Evaluation of supervised automated classification results for total map-area and for each land district: 1 - very poor; 2 - poor; 3 - imperfect; 4 - satisfactory; 5 - good; and 6 - very good. *Indicates that the particular class does not occur in appreciable quantity.

CLASS	KNIFE RIVERS DISTRICT (2B)	MACK LAKE DIST. (2A)	SEAL RIVER DIST. 1A	LOFTHOUSE-LOVETT LAKES DISTR			COASTAL DIST. 1C	TOTAL MAPSHEET
				TRANSITION 1B-2B	1B	TRANSITION 1B-1C		
1 Sedge-bs-tl	1	3	2	3	2	3	1	3-
2 Open black spruce	4*	5	4-	4-	4-	3	3	4-
3 Stonefields	5*	6*	4+	5*	6*	5*	4*	4+
4 Willow/ald/birch	6*	6*	6*	6*	6*	6*	4+	4+
5 Water	5	5	6	5	5	5	5	5+
6 Peat plateaus	4	4+	5*	4	3-4	4+	1	4
7 Peat polygons	5*	2	4	3	4	2-3	2	4-
8 Lichen-sand-till	4-	4	4+	4-	3	2	3	3+
9 Patterned fens	6*	6*	2	3	2	3	1	3-
10 Unclassified	5	3	5	2	3	5	4	4
All Classes	4	4+	4	4	4	4	2	4

would vary according to districts. Confusion would be reduced considerably. However, it would also increase the required time for training and classification of a satellite frame 5 to 20 times, assuming that about 5 to 20 land districts are likely to occur in one satellite frame. Although this procedure would not drastically increase computer time, it would require a number of days of interactive supervised training, with the probable result of a 20- or fewer class legend, varying according to land district and heavily biased toward vegetation.

Unsupervised Automated Classification

In the three test areas (Seal River, Mack Lake and Lovett Lake), supervised classification was carried out using a multidimensional histogram approach (Goldberg and Shlien, 1975). In this method, the image to be classified is scanned and a four-dimensional histogram of intensity vectors is created. By choosing a threshold, the intensity vectors can be grouped into clusters. The interpreter chooses the threshold value. This procedure makes the approach interactive; the interpreter can break up specific cluster by raising the threshold value and treating only the vectors belonging to that cluster (Goldberg and Shlien, 1975). Figure 7, showing the Long Island area and part of the Lovett Lake test

area, permits the comparison of an unsupervised clustering (A), a supervised classification (B), and interpretation (c) of 1:100,000 scale black and white photographs. (C) shows typical biophysical land systems as complexes of land types, with each primary land type identified by a class and percentage of occurrence. The unsupervised classification provides the most detailed map themes. (A) is the result of about 16 clusters, only 10 of which occur in considerable quantity. (B) maps only 9 class groups.

The unsupervised clusters are not better classes or land types than the ones derived from supervised classification. In fact, the results of the supervised classification closer to an ecologically desirable map than are the results of the unsupervised classification.

The advantage then of the unsupervised technique is that the computer, with little user interaction and time, gives an impression of which objects are separable. However, relating clusters of practical classes and themes and grouping them is usually not a simple task. It can be time-consuming and still not provide the most desirable classification. In addition, such 'editing' requires at least as much ground control as is needed for supervised classification.

Use of Multidate Imagery for Automated Classification

The visual interpretation of satellite images has demonstrated the value of using multidate satellite imagery for classification purposes (Thie *et al.*, 1974; see Figure 8). Kalensky (1974) also reported improved classification accuracy for vegetation mapping using multidate information. Winter imagery, especially, contains information that is complementary to summer date. Figure 9 demonstrated the considerable difference between the spectral characteristics of a summer and a winter channel. As a result of the very special associations among vegetation, soils and permafrost in this subarctic area, winter imagery enhances, for example, the distribution of well-drained glaciofluvial and beach deposits. The Seal River test area was used for the multidate evaluation as it has suitable representation of mineral and organic soils, and vegetation is not visibly disturbed. Both supervised and unsupervised classifications were applied to a tape composed of three summer channels and one winter channel. The addition of the snow covered image was mainly beneficial for areas covered with vegetation (trees and shrubs) that is sufficiently high enough to penetrate the snow layer and dense enough to lower reflectance values of

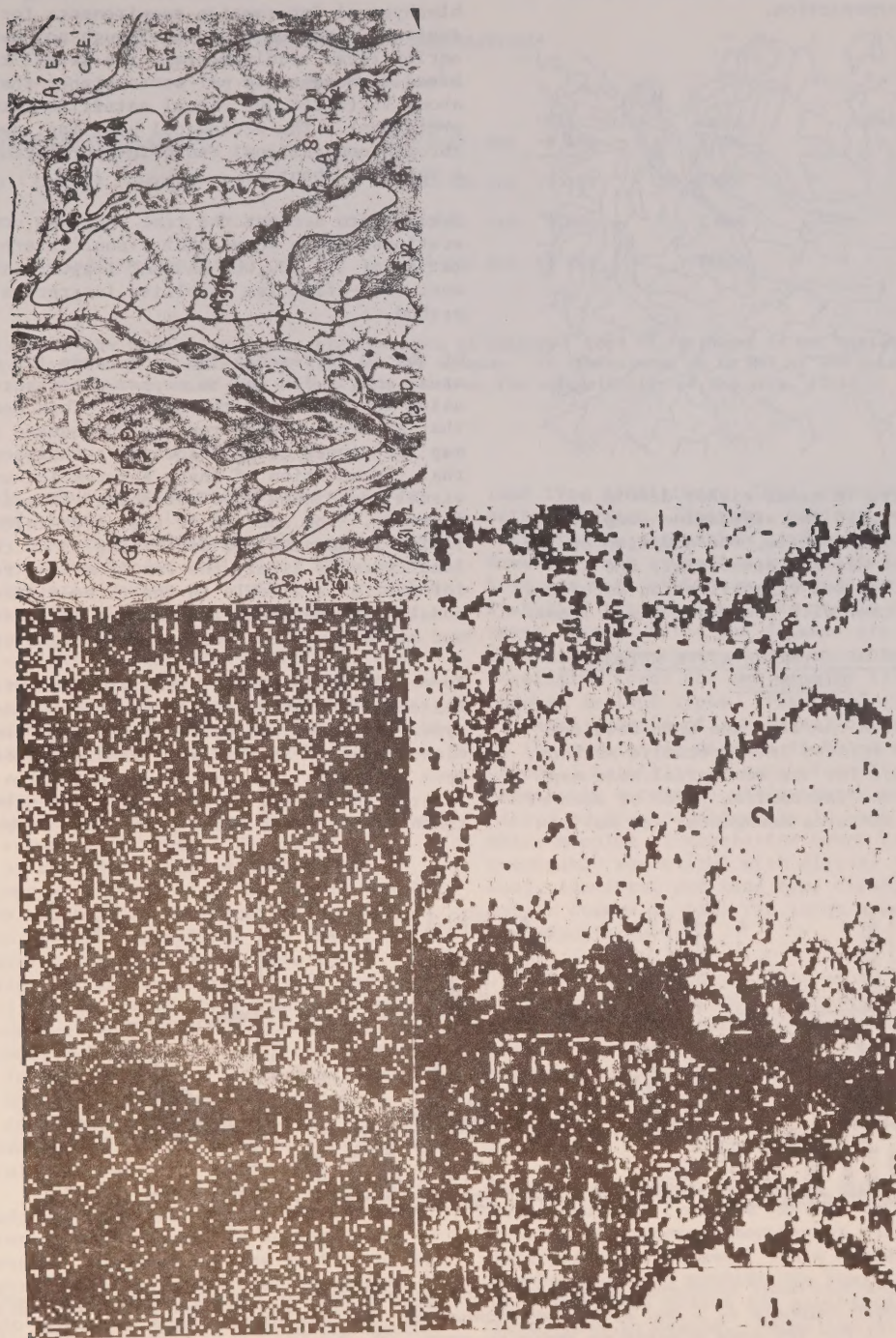


Figure 7: Comparison of unsupervised A, supervised B and interpretation of B&W aerial photographs. Colour scheme of A is explained in Figure 4. C shows land system with percentage of land types.

Figure 8: Land system boundaries derived from summer (closed lines) and winter (broken lines) satellite imagery through visual interpretation.



snow. However, in areas either devoid of vegetation or with the vegetation completely covered by a snow mantle, the addition of the winter channel was not beneficial, and occasionally lowered classification accuracy. Such was the case with the stone field theme.

COMPARISON OF INTERPRETATIVE METHODS - DISCUSSION

Table 6 compares the time and cost requirements for the various interpretative methods, including those for the ecological base map. In addition, the information value of each of the maps for resource management was subjective

tively estimated, based on the requirements for regional resource planning. Out of a possible value of 100 (i.e. satisfying most biophysical information requirements for regional resource planning though not necessarily local requirements), the satellite-based techniques do not score higher than about 15 (1:250,000 visual satellite interpretation). The ecological base map, made through conventional photo-interpretation, has a value of about 75.

Taking into account the time and cost considerations, Table shows that visual interpretation of 1:1,000,000 LANDSAT imagery is the most cost-effective satellite interpretation method.

Of the 50 representative land types for the area, only a few can be mapped satisfactorily using the satellite techniques. This means that spectral signatures are inadequate to map land types using automated techniques and that the addition of shape information using visual techniques does not change this significantly. The success of the photo-interpretation in mapping and describing 43 of the 50 land types is likely the result of the relief information available in the three-dimensional model, and the shape information of landforms and micro-landforms, rather than signatures.

To obtain a reasonable classification with the tested interpretative methods, the 50 land types (classes) has to be joined into broader class groups. In this way, 15 class groups were separable with the visual satellite interpretation and about 10 with the automated techniques. These class groups are so broad

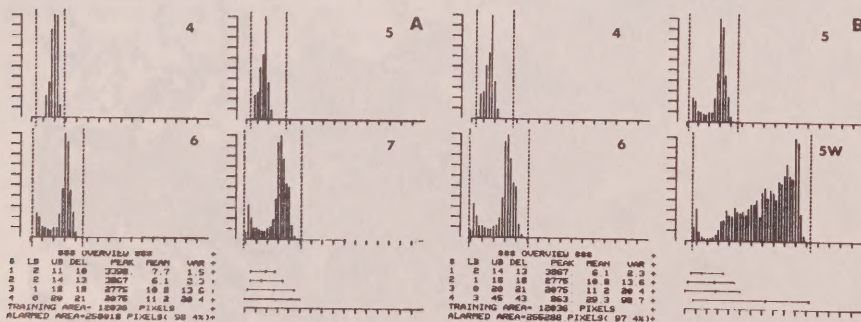


Figure 9: One-dimensional histogram displays of the intensities of the composite summer-winter image (summer channels 4, 5 and 6; winter channel 5W) and the summer image (summer channels 4, 5, 6 and 7) for the same clustering training area. The horizontal axis displays the reflectance values (from 1-63) and the vertical axis, the frequency of pixels with those values. Note the wide range of distribution and the skew towards light reflectance values of (5W).

Table 6: Time and Cost Considerations

TIME AND COST CONSIDERATIONS*					
Per 13,000 Km ²					
		Time	Mat.	Labor	Information Value
1:1,000,000 LANDSAT (VISUAL)		15-20 hrs	\$ 100	\$ 600	8-10
1:250,000 LANDSAT (VISUAL)		80-100 hrs	\$ 100	\$3000	15
AUTOMATED LANDSAT		15-20 hrs	\$2000	\$ 600	5-10
1:100,000 Ecological Base Map		120-160 hrs	\$ 200	\$4800	75

* Only listed is the time and cost for interpretation of imagery. Cost of fieldwork is not included. Fieldwork cost can be considered the same for all methods. It constitutes up to 80% of the total survey cost for conventional type surveys, depending on the accessibility of the area. (Thie et al, 1974).

that their value to resource managers is very restricted, hence the low rating (5-15) in Table 6. The study indicates that an increase in the physiographic or ecological complexity of the land area causes an increase in misclassification with all satellite interpretative techniques. The more complex areas have a greater variety of surficial materials, vegetation and relief. The present resolution as well as the lack of detailed relief information appears to be the main limiting factor to apply satellite interpretative methods.

This study demonstrates that classification methods based only on spectral signatures did not map enough land types. The relative success of the visual analysis as compared with automated methods might be due to the use of shapes and spatial patterns in the interpretative process, as well as the use of multi-date images. This apparently more than compensates for the loss in spectral information. It can be argued that present automated interpretative techniques allow geometric corrections, multirate overlays, and simple spatial feature analysis. While they should improve classification results, they also require additional computer and training time. Costs involved *at present* make it unattractive for operational use.

This study was unusually simple for Canadian circumstances with regards to ecology and physiography. The land surface is flat or at most lightly sloping. Surficial materials cover extensive areas and are not mixed. Most important, due to a lack of disturbing agents, vegetation and therefore its signatures can be considered a good indicator of ecosystem or

land type conditions. Thus, changes in relief, soil, drainage, landform, habitat, etc. are reflected in vegetation gradients or boundaries. However, this exceptional situation does not hold for most of Canada. Vegetation has been disturbed through land use, and in northern areas, forest fires and disease are even more important. In those situations, changes in vegetative cover are not usually related to changes in land types. Figure 10 gives a striking example of the impact of forest fires on the vegetation pattern of the boreal zone in Canada. Satellite imagery classification, especially automated performance, can be expected to drop considerably in such areas. While mapping of vegetative cover type can be reasonably successful with digital techniques, soil, landform, and land type classifications appear doomed to fail for large areas, except large wetlands.

The above mentioned limitations do not apply to air photo interpretation techniques. Through the use of relief and shape information, fire boundaries can be identified, and only those vegetation boundaries are used that are considered to reflect land type conditions.

CONCLUSIONS

Taking into consideration the usefulness of data resulting from the various interpretative methods for resource management purposes, photo-interpretation of small scale aerial photographs *presently* provide the best cost- and data-effective method for ecological land classification in Canada. Satellite data should be used in a complementary way; that is, to assess and delineate environmental dynamic phenomena,



Figure 10: Forest fire patterns in the boreal zone near Black Lake, Saskatchewan. The snow cover on this 7 March, 1974 LANDSAT image enhances the complex forest fire pattern. Some areas (A) were burned more than 100 years ago, others very recently (B); most of the area is burned repeatedly. This image shows forest fires to be an integral part of the boreal ecosystem.

and to delineate land districts.

Visual interpretation of 1:1,000,000 multirate satellite imagery provides an operational alternative only if more than 20,000 km² per man-year has to be mapped, and then only in ecologically and physiographically simple areas: arctic, subarctic, and large wetlands in the boreal zone. Automated classification appears, *at present*, unsuitable for ecological land classification in Canada. While certain simple maps can be made for arctic and subarctic areas and boreal wetlands, the practical usefulness of this information is somewhat in doubt. It is expected that this assessment will change when a significant breakthrough occurs in the automated analysis of shapes and textures.

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BIOPHYSICAL MAPPING IN THE MACKENZIE VALLEY

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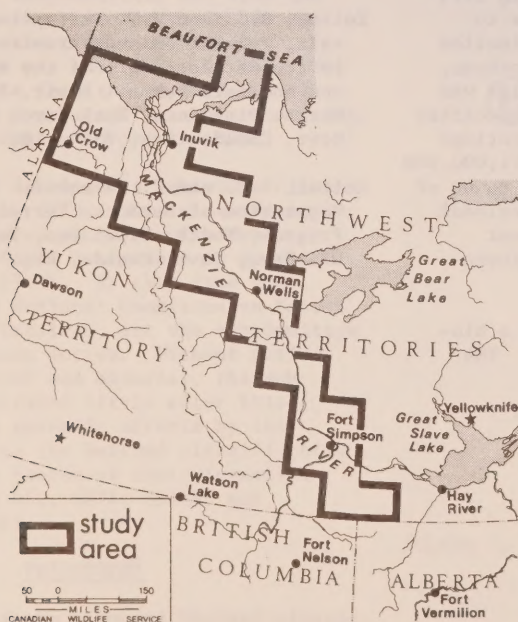
In 1970, the Geological Survey of Canada (GSC) undertook a three-year program of mapping the surficial deposits in the Mackenzie Valley and northern Yukon. As environmental concerns relating to a possible energy transportation corridor became evident, the survey was expanded to include such terrain sensitivity indicators as vegetation and soils. In 1971, the Canadian Forestry Service was invited to provide the vegetation input, and the Soil Research Institute was invited to provide pedological information.

The resulting survey was clearly a surficial geology study, with vegetation and soils added on. Thus, it was never intended nor organized to be a biophysical study. The investigators of the vegetation-soils aspect had two viable choices: 1. to use the mapping units identified by the GSC to characterize the vegetation and soils of the area; and 2. to map biophysical characteristics of the area. The size of the area (120,000 mi²) and time

constraints (two field seasons) were important constraints, as each of the two teams were to cover about 30,000 mi² a year.

The northern team chose to use the mapping units prepared by the GSC at a scale of 1:125,000. The mapping units, as conceived by the GSC, were to be based strictly on the genesis of the surface materials. The vegetation-soils team was successful in persuading the surficial geologists to add such features as texture and slope to their mapping criteria. This made the resulting units more suitable to vegetation-soil interpretation and paved the way to a modified biophysical classification. The modification was necessary, as the main thrust of the project was not productivity of the terrain, but sensitivity to disturbance.

The southern team chose to map the area, applying a biophysical classification, as interpreted by the investigator. This study



very rapidly became a nightmarish exercise in mapping and air photo interpretation of the huge area at the detriment of field studies, as both the surficial geology mapping and the biophysical mapping were proceeding concurrently, without effective interchange of ideas or maps. In 1972, the Soil Research Institute became involved with the southern team and produced an integrated report with the Geological Survey (Tarnocai, 1973).

The northern team, free of the burden of duplicating the mapping effort of the GSC, concentrated on studying and understanding the relationships between landforms (identified by the GSC), vegetation, and soil (active layer). Two avenues were taken in the reporting: one presented the findings of the vegetation-soils team only (Zoltai and Pettapiece, 1973), and the second avenue was to integrate the vegetation-soil-active layer results into the legend of the map by GSC. In the legend, the Land Zones (e.g. Land or Site Regions) were established on the basis of vegetation chrono-sequence and permafrost characteristics. Within each Land Zone (Region), the mapping units were characterized as to vegetation and soils. The stable and fire-originated vegetation were indicated for the major moisture regimes (drainage classes) of each landform. Likewise, the soil texture, depth of active layer and frost-induced micro-relief were given for each major drainage class of each mapping unit in the different Land Zones (Regions).

This study and subsequent field work in 1973 (Zoltai and Tarnocai, 1974) enables us to develop a terrain sensitivity classification (Van Eyk and Zoltai, 1975). In this scheme, each drainage class of all mapping units was rated as to the expected reaction to specified surface disturbances. The resulting ratings were generalized and portrayed on a 1:1,000,000 map. This map, while too generalized to be of value at the local level, shows the regional picture and puts southern (boreal forest features) on the same scale as the northern (tundra) features.

The cost of the survey in relation to a biophysical survey cannot be determined. The

GSC, being the lead agency, decided the various aspects of the field investigations. Thus, much effort may be spent on an area of complex glacial history, while other areas of simple depositional history may receive little attention, although this may be an area sensitive to disturbances.

The northern team consisted of two or three professional Pleistocene geologists, a geophysicist, a vegetation man and a soils man. With support staff (technicians, pilots, students, labourers and cook) the whole crew numbered about 16 persons. A helicopter and a Beaver aircraft supplied full-time transportation. A biophysical survey, yielding comparable results, could have been completed by about half the crew in the field, with comparable savings.

My estimate is that such a survey could be conducted for \$175,000 to cover 30,000 mi², or about \$6/mi².

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WETLAND CLASSIFICATION

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INTRODUCTION

In 1970 the National Committee on Forest Land established a subcommittee on Organic Terrain Classification. The immediate task of this subcommittee was to develop a system of organic terrain classification application to various land use purposes. The classification system was to be compatible with our current methods of land resource surveying, notably the Biophysical Land Classification.

The subcommittee consisted of a panel of eight experts in wetland research under my chairmanship. Each panel member represented the geographic area of a province, except that there was one representative from the three Maritime Provinces. Each member of the subcommittee was to organize provincial study groups consisting of workers in various disciplines, all experienced in wetland investigations. Thus each panel member represented not only his own thoughts and expertise on the subcommittee, but also the thoughts of a variety of experts in his own region. At the same time, an intensive literature review was undertaken by the panel members to benefit from the experiences of other workers in Canada and in other countries, especially in northern Europe and USSR.

The subcommittee developed a tentative classification system by 1973. This classification system was presented at the Fourth North American Forest Soils Conference at Quebec (Zoltai *et al.*, 1973). By this time the parent body, the National Committee on Forest Land, had been dissolved, but the subcommittee was asked to remain active. Without active support, both moral and material, the subcommittee accomplished little after this time, other than sporadic efforts by its members to utilize the Wetland classification framework in the course of their investigations (Jeglum *et al.*, 1974; Zoltai and Tarnocai, 1975a,b).

PHILOSOPHY

The philosophy of the proposed Wetland classi-

fication is based on the premise that wetlands are ecosystems on which a multitude of environmental factors are acting through time and changing climatic conditions (Figure 1). A classification that would stress only single or few features would find limited usefulness for many resource users. By recognizing a wide spectrum of environmental influences, the needs of various land users are met.

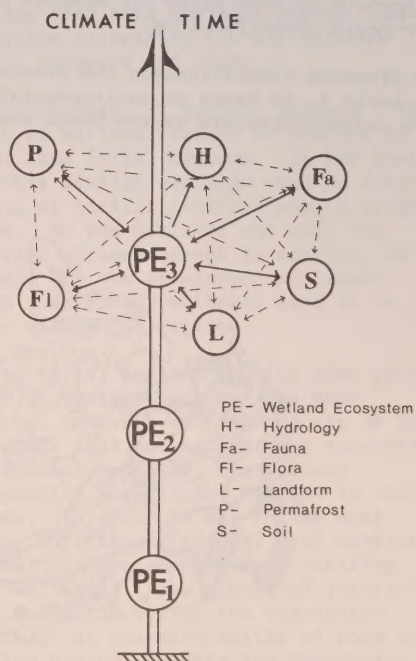


Figure 1: Diagram of interactions between environmental parameters and wetland and wetland ecosystems through time and changing climate.

The proposed classification is presented in a hierarchical framework. The higher levels have been assigned ecosystemic definitive and descriptive criteria, and the lower levels have more specific, user-related criteria.

Wetlands are not conceptually different from drylands. In the past, the differences between drylands and wetlands were stressed, creating the impression that wetlands are by their nature entirely different from drylands. Wetlands have landforms (e.g. surface forms and materials), just as drylands have. Wetlands have different moisture conditions on quantitative, qualitative and temporal bases, as do drylands. Wetlands possess local climates as do drylands. Perhaps the only meaningful difference is that wetlands can manufacture their own materials and are therefore capable of changing their own site characteristics. Although site qualities may change on drylands also, the change in wetlands (especially in peatlands) is more rapid and obvious. Wetlands are, therefore, more dynamic ecosystems than drylands.

PROPOSED CLASSIFICATION*

**See Appendix of this paper for details on the proposed classification.*

In the proposed classification the broadest level, Level 1, is based on environmental factors which contribute to the broad physi-

ogonomy of the wetlands. The various kinds of wetlands recognized were Bogs, Fens, Swamps, Marches and Shallow Lakes. Each of these are defined within regions as to moisture conditions, materials, nutrient conditions, water movement, development dynamics and vegetation. Level 2, a subdivision of Level 1, is based primarily on the surface morphology of the wetlands including the distribution of surface water and, in some cases, the morphology of the confining basin. Being a subdivision of Level 1, all the environmental parameters considered for Level 1 also apply to this level. At Level 3 the wetland types identified at Level 2 are further subdivided on the basis of broad vegetation, edaphic, hydrologic or developmental dynamic characteristics. Level 4, the most detailed level, was left open to allow further subdivision on the basis of the specialized needs of various disciplines, e.g. wildlife, botany, forestry, engineering, etc.

This hierarchical system allows different disciplines to follow a common path and diverge only at the most detailed, local study level. This overcomes the greatest difficulty that the subcommittee found: that of terminology. The same word may have totally or subtly different meanings to different persons or disciplines. Thus "muskey", when used as a scientific term, has as many different definitions as there were people working with them. As a result of our efforts, in the Mackenzie Valley, home of the "muskey", now even the

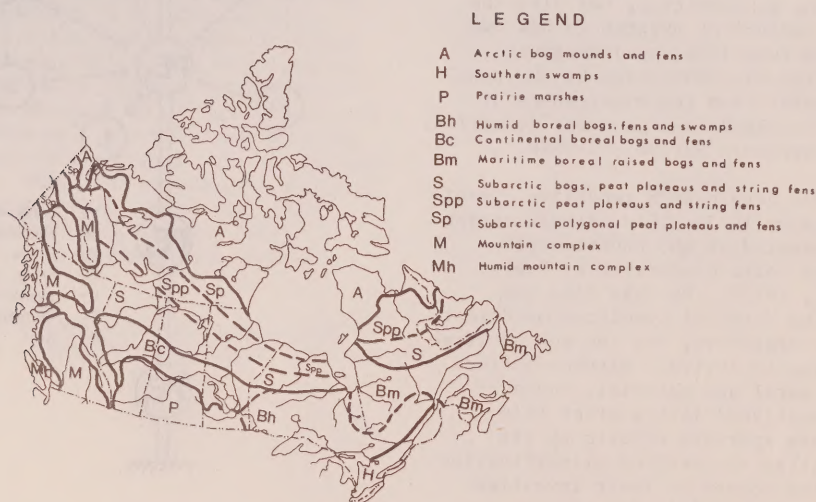


Figure 2. Broad wetland regions of Canada.

engineers are differentiating the fens from other kinds of organic terrain because of their distinctive and peculiar permafrost and groundwater characteristics.

Another advantage of the proposed system is that it recognizes the dynamic processes that take place in the wetlands. Wetlands, being dynamic ecosystems, are subject to change due to their own development or due to interference with the natural system. When we examine a wetland at a point in time, we may happen to see it in a stage which is in equilibrium with its present environment. Other wetlands may be in a transitional stage, as a response to a change in its environment. Because in the classification system no single characteristic determines the type of wetland, such transitional stages do not cause great problems.

A further advantage of the proposed classification system is that it adopts very readily to the Land (Site) Regions. It has been found that Wetland Regions can be established across Canada based on occurrence and dynamics of wetlands on broad areas. An initial map of Wetland Regions of Canada (Figure 2) was presented at the 4th North American Forest Soils meeting (Zoltai *et al.*, 1973). Although portions of this map were since revised, the concept of such Wetland Regions is proving very useful when investigating wetlands on a regional basis.

FUTURE NEEDS

The work of the Subcommittee on Organic Terrain Classification is not completed. In my opinion, the following tasks remain to be done:

1. Establishment of pilot projects
2. Establishment of Wetland Regions
3. Characterization of wetland forms

1. Pilot Projects - The proposed classification is the concept of the subcommittee and the contributing local study groups of a system of wetland classification. It incorporates many old, tested ideas, but it also introduces new combinations deemphasizing some, and reinforcing others. It is the belief of this subcommittee that this classification is usable, and that it is suitable for the needs of a wide spectrum of resource users. However, we do not know whether this is true. We will not know until it is field tested and evaluated by multidisciplinary groups.

The importance of wetlands in Canada hardly needs emphasis. To illustrate the state of

our knowledge, we do not even know how much wetlands we have, never mind what kinds of wetlands we have. A common estimate is that about 500,000 mi² or 12% of the land surface of Canada is covered by wetlands (MacFarlane, 1969). In Ontario, the estimates are that peatlands cover some 165,000 mi², or 49% of the Province's land area (Ketcheson & Jeglum, 1972). A current estimate of peatlands in Alberta, a "prairie" province, is 31,000 mi², or 12% of the surface of the Province is in peatlands (R. Valleau, 1974, pers. comm.) In New Brunswick there are 2,700 mi² of peatland, covering about 10% of the Province (Korpiaakko, 1975).

A knowledge of the resource is an essential first step in planning the utilization of the wetland resource. The knowledge of the wetlands includes not only its geographical distribution, but its nature, dynamics and potential. Thus a workable, wide-spectrum classification system is a prerequisite to resource management and planning. Pilot projects, conducted by multidisciplinary teams could evaluate the tentative classification system in various parts of the country. Modifications and improvements resulting from such projects should lead to a system acceptable for all wetland resource managers and users.

2. Establishment of Wetland Regions - The concept of Wetland Regions is similar to that of Land (Site) Regions. It has been noted that similar wetlands tend to develop in areas of similar landform within broad regions. On the wetlands not only the vegetation chronosequence is similar, as on drylands, but the developmental trends through time on the wetlands tend to be similar within the regions.

The Land (Site) Regions can, to some extent, be used as Wetland Regions. In many instances, however, differences may be found on drylands that necessitate the recognition of a regional boundary, but without corresponding significant changes in the wetlands. This can be due to the more uniform, but often stressful soil moisture and local climate conditions prevailing in the wetlands. As a matter of interest, in the Mackenzie Valley the vegetation and permafrost characteristics of bogs in a Wetland Region resemble the vegetation and permafrost characteristics of moist drylands one region on regions farther north.

The similarity and yet not complete correspondence of Wetland Regions and Land

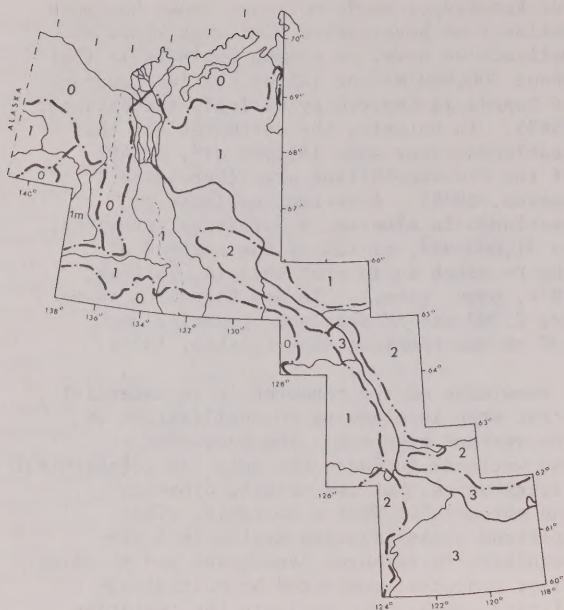


Figure 3. Land Regions of the Mackenzie Valley, N.W.T.

(Site) Regions is illustrated in Figures 3 and 4. Here the Regions in the Mackenzie Valley, comprising some 120,000 mi² are juxtaposed, showing that some boundaries coincide closely, but others do not. This suggests that while many Land (Site) Regions are also Wetland Regions, the establishment of Wetland Regions should be pursued, especially if the thrust of the particular study is oriented towards wetlands. For dominantly dryland-oriented studies, the Land (Site) Regions can be accepted as being suitable for the characterization of wetlands, realizing the possibility that the wetlands may extend into the neighbouring Land Regions.

The value of Wetland Regions is obvious. Because of similar developmental trends the wetlands can be defined and described with a reasonable degree of accuracy within regions. The response to development or disruption will also be similar within regions, adding a powerful tool for predicting the consequences of such disruptions. Wetlands Regions facilitate the description, characterization and response of wetlands, allowing a meaningful planning of their management and utilization.

3. Characterization of wetlands forms - Wetland forms can be defined as (1) the surface form of the wetland, its position in relation

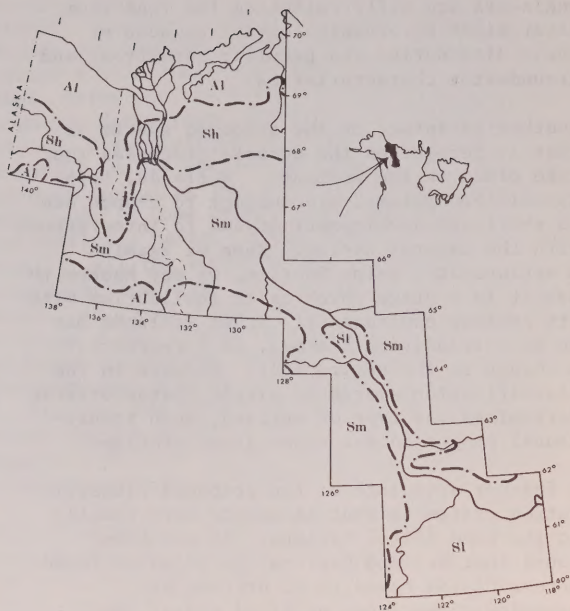


Figure 4. Wetland Regions of the Mackenzie Valley, N.W.T.

to the containing or adjoining mineral terrain or open water, and (2) the material of the wetland. Field investigations show that characteristic wetland forms tend to develop within Wetland Regions. They are readily recognizable and mappable at a reconnaissance level. Their number is finite and within manageable dimensions.

Peatlands types were found to be useful for wetland classification by Heinselman (1963). The initially-proposed wetland classification for the Biophysical Land Classification (Adams and Zoltai, 1969) made use of wetland forms, and their definition and use was further extended by Tarnocai (1970). In practice, it was found that in the Mackenzie Valley there are only seven distinct perennially frozen peatland forms (Zoltai & Tarnocai, 1975a). Each of these could be described and characterized, and the descriptions can be used with a high degree of confidence to characterize the external, internal and dynamic properties of similar wetlands in the region.

Figures 5 to 9 in the appendix show a graphical characterization of wetland forms. Such diagrams and photographs should accompany the description of the internal and external characteristics of the biotic and abiotic environment of different types of peatlands.

In the opinion of the Subcommittee, a registry of peatland forms should be kept in which the detailed description and characterization of various wetland types would be kept, with periodic publications. This would ensure that the terminology will not change, achieving a degree of stability and avoiding confusion. It would ensure that superficially similar, but basically different wetlands types will not be confused in the mind of the investigator or his audience. We believe that such a scheme would go a long way toward maintaining communication between individual works and between various disciplines.

RECOMMENDATIONS

It is my recommendation that a subcommittee or working group of Wetland Classification be reestablished. The tasks of such a group should include the finalization of the wetland classification system and the promotion of its use throughout Canada. Some of the immediate tasks may be:

1. Organizaing and implementing multidisciplinary pilot projects of wetland classification in different parts of the country.
2. Defining and refining the Wetland Region of Canada, as a spatial framework for regional wetland studies.
3. Initiating and maintaining a registry of wetland types, and preparing the publication of this information as needed.

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APPENDIX

OUTLINE OF PROPOSED WETLAND CLASSIFICATION*

At present, the subcommittee has not finalized a wetland classification. However, the following is a favoured approach which complies with the terms of reference and objectives of the subcommittee, but has not yet been tested or scrutinized by possible users. There are four proposed levels of classification:

Level 1 - This level is the most generalized and is based on site features which either constitute or contribute to the physiognomy of the wetlands. The units exhibit considerable integrity regarding surface morphology, soil type, nutrient and moisture regimes, drainage regime, and vegetative cover. The main wetland classes are: bogs, fens, marshes, swamps, and shallow open waters (Table 1). The following are definitions of these terms, based on the work of several authors.

Bogs - Bogs are peat-covered areas or peat filled depressions with a high water table and a surface carpet or mosses, chiefly *Sphagnum*. The water table is at or near the surface in the spring, and slightly below during the remainder of the year. The mosses often form raised hummocks, separated by low, wet interstices. The bog surface is often raised, or if flat or level with the surrounding wetlands, it is virtually isolated from mineral soil waters. Hence the surface bog waters and peat are strongly acid and upper peat layers are extremely deficient in mineral nutrients. Peat is usually formed *in situ* under closed drainage and oxygen saturation is very low. Although bogs are usually covered with *Sphagnum*, sedges may grow on them. They may be treed or treeless, and they are frequently characterized by a layer of ericaceous shrubs.

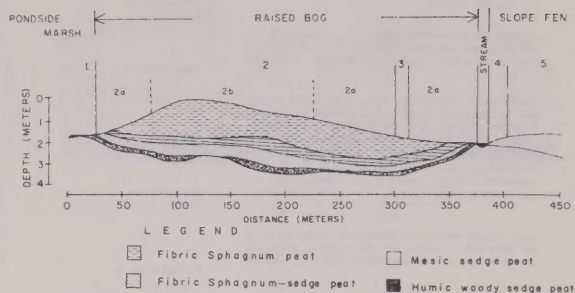


Figure 5a: Cross sectional diagram of a raised bog, maritime Boreal (Bm) Wetland Region.



Figure 5b: Ground view of a raised bog, Maritime Boreal (Bm) Wetland Region. The bog surface is nearly level on the crest, but begins to slope away from the viewer past the clump of trees.

* This Appendix has been added to Mr. S.C. Zoltai's original paper by the editor, to allow the widest possible distribution of the Wetland Classification Scheme. The Appendix is modified from the paper "Developing a Wetland Classification for Canada" by S.C. Zoltai, F.C. Pollett, J.K. Jeglum and G.D. Adams, in the proceedings of the 4th North American Forest Soils Conference, Quebec City, 1972, published by Les Presses de l'université Laval. 497-511

Table 1: Provisional key to wetland classes.

	CLASS
1. Well-defined wetland basins in which at least 75% of the area is occupied by central expanses of permanent open water less than 2 m in depth	Shallow Open Water
1. Wetlands where permanent open water is restricted to scattered small pools occupying less than 75% of the area, or where standing water is present only seasonally or not at all	Other Wetlands - 2.
2. Predominantly ombrotrophic wetlands, developed on acid peat forming a level, raised, or sloping surface with elevated hummocks and wet hollows, usually overlain by a continuous carpet of spongy moss dominated by <i>Sphagnum</i> , and supporting a layer of Ericaceous shrubs, with or without trees	Bog
2. Predominantly minerotrophic wetlands, on less acid peat or mineral soil, without a continuous moss substrate and with a water table persisting seasonally at or very near the surface.	Fen, Marsh and Swamp - 3.
3. Open wetlands with level or depressional surfaces except for low hummocks or ridges, and dominated by sedges and grasses. Pools of open water or drainage tracks may be present	Fen and Marsh - 4.
4. Wooded, non-bog wetlands usually with a flat or hummocky surface and supporting about 25% cover of trees or tall shrubs more than 1.5 m in height. Associated with stream courses, lake edges, subsurface drainage, glacial depressions, and hog margins	Swamp
4. An open, relatively uniform and consolidated surface occasionally with subparallel ridges or elevated islands, linear drainage features, and a dispersion of small pools. Surface vegetation consists of sedges and grasses and a sparse layer of shrubs and trees	Fen
4. An unconsolidated open, flat to depressional surface with clumps of emergent sedges, grasses, and reeds interspersed in standing water with occasional small pools and channels, or patches of bare soil exposed during seasonal water drawdowns. Often associated with open water in streams, flowage lakes, glacial depressions, or on marine terraces	Marsh

Table 2: Provisional and incomplete key to bogs.

	TYPE
1. Surface not raised above surrounding terrain	
2. Surface concave	Bowl Bog
2. Surface relatively level	
3. With abrupt marginal peat walls in permafrost terrain	Collapse Bog
3. Without marginal peat walls	
4. With small sink pools	Sinkhole Bog
4. Without sink pools	
5. Adjacent to water bodies	
6. Floating	Floating Bog (includes Floating Island Bogs)
6. Not floating	Shore Bog
5. Not adjacent to water	Flat Bog
1. Surface raised or appreciably sloping	
7. Surface level to irregular, but not conspicuously domed or sloping	
8. With frozen core	
9. With network of polygonal fissures	Polygonal Peat Plateau
9. Without fissures	
10. Without thaw pockets	Peat Plateau
10. With oval or irregular thaw pockets	Thermokarst Peat Plateau
8. Without frozen core	Bog Plateau
7. Surface domed or sloping	
11. Abruptly domed, usually in a fen matrix	
12. Frozen core	Palsa Bog
12. Without frozen core	Peat Mound Bog
11. Gently domed, sloping or with a "stepped" surface	
13. Topographically extensive	Blanket Bog (includes Slope Bogs)
13. Topographically confined, usually with central peats and/or marginal wet troughs (flats) and a marginal fen (lagg)	Raised Bog

Table 3: Provisional and incomplete key to fens.

	TYPE
1. Surface not raised above surrounding terrain except in low hummocks and ridges	
2. Surface pattern of ridges and depressions	
3. Subparallel pattern of ridges and furrows	String Fen (includes Ribbed Fen)
4. Broad pattern along lowland drainages	Seepage Fen (includes Water Track Fen)
4. Narrow ladderlike pattern along bog flanks	Net Fen
3. Reticulate pattern of ridges	
2. Without pronounced surface pattern	
5. Featureless, without surface water	
6. Adjacent to water bodies	
7. Floating	Floating Fen
7. Not floating	Shore Fen
6. Not adjacent to water	
8. Fitted to narrow drainages	Draw Fen
8. Without obvious drainage control	Horizontal Fen
5. With surface water or filled depressions	
9. With round or irregular ponds	Pond Fen
9. Depressed thaw hollows	Collapse Fen
1. Surface raised or appreciably sloping	
10. Mounds with frozen core in pattern fens	Palsa Fen
10. Without frozen core	
11. Surface irregular due to upwelling water	Spring Fen
11. Surface regular but sloping	Slope Fen

Table 4: Provisional and incomplete key to swamps.

	TYPE
1. Adjacent to permanent water body	
2. Adjacent to moving water	Alluvial swamps
2. Adjacent to non-moving water	Lakeside swamps
1. Not adjacent to permanent water body	
3. In topographically defined basins	
4. On perimeter of peatlands	Peat margin swamps
4. Not on perimeter of peatlands	Catchment swamps
3. Not in topographically defined basins	Seepage swamps

Table 5: Provisional and incomplete key to marshes.

	CLASS
1. Adjacent to or influenced by marine tidal water	
2. In river estuaries or adjoining bays where tidal flats, numerous channels and pools are inundated by fresh, brackish or salt-water	Estuarine Marsh
2. On marine terraces remote from estuaries, or in embayments or lagoons behind barrier beaches, where there is periodic inundation by tidal brackish and saltwater	Coastal Marsh
1. Adjacent to inland water body	
3. Adjacent to permanent water body	
4. Adjacent to moving water	
5. Occupying water courses or flood plains	Fluvial Marsh
4. Adjacent to standing water	
5. Occupying lake shores or bays of flowage lakes	Lentic Marsh
3. Not adjacent to permanent water body	
4. Occupying topographically defined basins	Catchment Marsh
4. Not in topographically defined basins, usually at low elevations or at the base of slopes	Seepage Marsh

Fens - Fens are peatlands characterized by surface layers of poorly-to moderately-decomposed peat, often with well-decomposed peat near the base. They are covered by a dominant component of sedges, although grasses and reeds may be associated in local pools. *Sphagnum* is usually subordinate or absent, with the more exacting mosses being common. Often there is much low-to medium-height strub cover and sometimes a sparse layer of trees. The waters and peats are less acid than in bogs of the same area, and sometimes show somewhat alkaline reactions. Fens usually develop in restricted drainage situations where oxygen saturation is relatively low and mineral supply is restricted. Usually very slow internal drainage occurs through seepage down very low gradient slopes, although sheet surface flow may occur during spring melt or period of heavy precipitation.

Swamps - Swamps are wooded wetlands where standing to gently-flowing waters occur seasonally or persist for long periods on the surface. Frequently there is an abundance of pools and channels indicating subsurface water flow. The substrate is usually continually waterlogged. Waters are circumneutral to moderately acid in reaction, and show little deficiency in oxygen or in mineral nutrients. The substrate consists of mixtures of transported mineral and organic sediments, or peat deposited *in situ*. The vegetation cover may consist of coniferous or deciduous trees, tall shrubs, herbs, and mosses. In some regions, *Sphagnum* may be abundant.

Marshes - Marshes are grassy wet areas, periodically inundated up to a depth of 2 m or less with standing or slowly-moving water. Surface water levels may fluctuate seasonally, with declining levels exposing drawdown zones of matted vegetation or mud flats. Marshes are subject to a gravitational water table, but water remains within the rooting zone of plants during at least part of the growing season. The substratum usually consists of mineral or organic soils with a high mineral content, but there is little peat accumulation. Waters are usually circumneutral to alkaline, and there is a relatively high oxygen saturation. Marshes characteristically show zonal or mosaic surface patterns of vegetation, comprised of unconsolidated grass and sedge sods, frequently interspersed with channels or pools of open water. Marshes may be bordered by peripheral bands of trees and shrubs, but the predominant vegetation consists of a variety of emergent nonwoody plants such as rushes, reeds, reedgrasses, and sedges. Where open water areas occur, a variety of submerged and floating aquatic plants flourish.

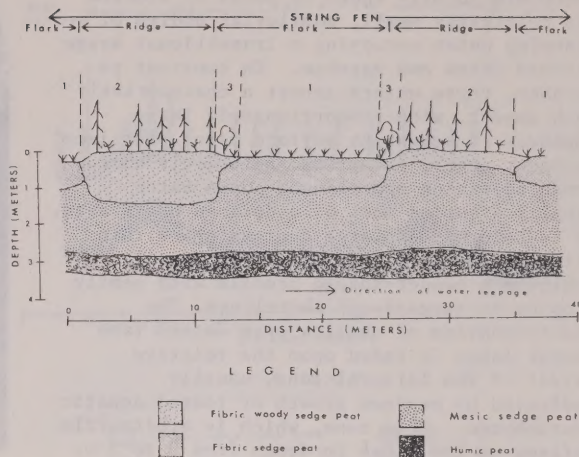


Figure 6a: Cross sectional diagram of a string fen, Continental Boreal (Bc) Wetland Region



Figure 6b: Aerial view of a string fen, Continental Boreal (Bc) Wetland Region.

Shallow Open Waters - Shall open waters, which are locally known as ponds or sloughs are relatively small, nonfluvial bodies of standing water occupying a transitional stage between lakes and marshes. In contrast to marshes, these waters impart a characteristic open aspect, with proportionately large expanses of permanent surface water that lack emergent cover, except for relatively narrow zones adjoining shorelines. Open water usually occupies most of a defined basin area, or is held within large depressions within extensive peats mats. The basin usually exhibits a saucer-shaped profile with gently sloping or recessional shorelines. The discrimination of shallow open waters from deeper lakes is based upon the relative extent of the littoral zone, usually indicated by maximum growth of rooted aquatic macrophytes. This zone, which is arbitrarily defined as the range in depth from 0 to 2 m, usually extends to the middle of the basin or occupies at least 75% of the basin area, with remaining portions occasionally attaining greater depths. Shorelines may be firm, soft, or floating, and they consist of materials varying from rock or silt to organic deposits.



Figure 7a: Ground view of a bowl bog, Humid Boreal (Bh) Wetland Region, looking from the centre toward the rim of the bog.

Forms of wetlands which are transitional between the classes described also occur. In general, the wetlands develop from marshes to fens to bogs and in certain areas bogs may develop into swamps. Many other wetland successions have been recorded; for example, in certain regions, swamps develop into bogs. Such transitional stages may be difficult to classify: it has been proposed that such stages, if identifiable, be named by composite names such as bogfens, fenmarshes, etc.

Level 2 - This level is based primarily on surface morphology of the wetlands, including the distribution of surface water, and in some cases, on the morphology of the confining basin. Such features as raised or level surfaces, patterns of ridges, depressions, or pools are noted, as shown by the key developed by Rowe (Tables 2 and 3). In contrast to bogs and fens, the marshes and swamps are not readily characterized by surface morphology. The association of marshes and swamps to hydrotopographic features (rivers, lakes, slopes, etc.) can be used to differentiate them (Tables 4 and 5). Shallow open waters may be classified according to the adjoining wetland or land types, e.g. mineral pools, bog pools, march pools, etc.

Level 3 - At level 3, the wetland types identified in Level 2 are defined on the basis of their vegetation characteristics.

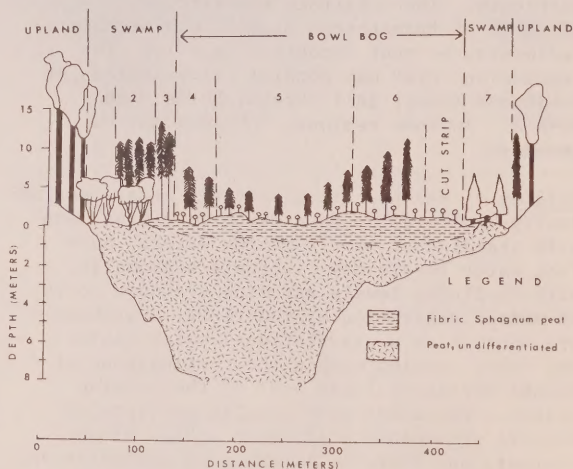


Figure 7b: Cross sectional diagram of a bowl bog, Humid Boreal (Bh) Wetland Region.

At this level, regional environmental influences, such as regional climate, edaphic conditions, or trophic levels become more important in classification and, subsequently, wetland subdivisions may be defined for each wetland region. For example, a catchment swamp in the St. Lawrence Lowlands may support a heavy growth of hardwood forest, but further north, coniferous forests become the dominant vegetation type, whereas in sub-arctic regions, tall shrubs will be growing on such swamps.

Level 4 - In the most detailed of classification, the specialized needs of disciplines are recognized. For example, if a particular interest lies in botany, the wetlands can be further subdivided into floristic units; wetland units can be evaluated on basis of engineering qualities, etc.

With the present information available concerning wetlands in Canada, the units in each level of classification can only be defined in descriptive terms. To prevent an uncontrolled proliferation of wetland types being incorporated into the literature, it might be desirable that each type in Level 2 be described from a "type" location. Each description would include as much information on the external and internal structure composition, and physical and chemical characteristics as possible. It is recommended by the subcommittee that a national body scrutinize these submissions and decide whether they are significantly distinct enough to be included in wetland subtypes. Some attempts at describing certain morphological wetland types have been made by Adams and Zoltai (1) and by Tarnocai (22). Examples of such wetland types, representative of different regions in Canada, are shown in Figures 1-5.

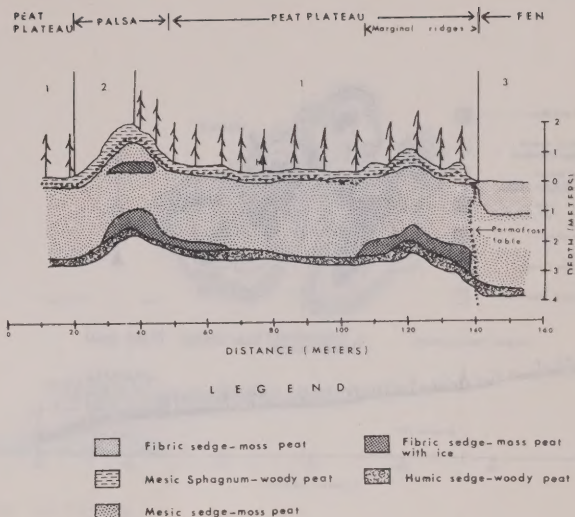


Figure 8a: Cross sectional diagram of a peat plateau and palsa, Mid-Subarctic



Figure 8b: Aerial view of the peat plateau-palsa complex shown in Figure 8a. The palsa is the elevated, treeless rise near the centre of the picture.

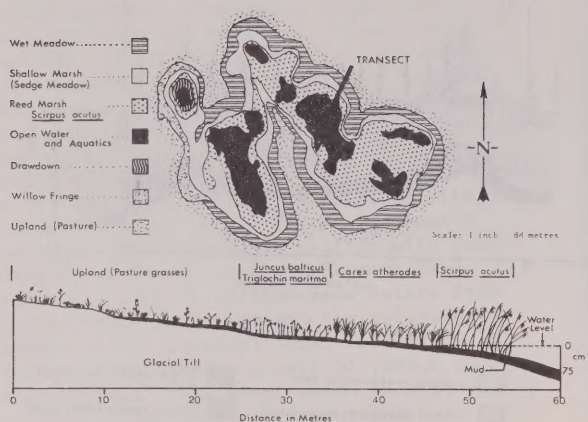


Figure 9a: Cross sectional diagram of a catchment marsh, Prairie (P) Wetland Region.



Figure 9b: Ground view of a catchment marsh, Prairie (P) Wetland Region.

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BIOPHYSICAL CLASSIFICATION IN NOVA SCOTIA
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